Thesis/
Reports
Robinson,
C.T.

Effects of Fire on Wilderness Stream Ecosystems in the Frank Church - River of no Return Wilderness Report of 1990 Studies

EFFECTS OF FIRE ON WILDERNESS STREAM ECOSYSTEMS

IN THE FRANK CHURCH - RIVER OF NO RETURN WILDERNESS

REPORT OF 1990 STUDIES

FINAL REPORT TO THE PAYETTE NATIONAL FOREST

EFFECTS OF FIRE ON WILDERNESS STREAM ECOSYSTEMS IN THE FRANK CHURCH - RIVER OF NO RETURN WILDERNESS

REPORT OF 1990 STUDIES

by

Christopher T. Robinson and G. Wayne Minshall

Stream Ecology Center
Department of Biological Sciences
Idaho State University
Pocatello, Idaho 83209

February 1991

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (CONT.)

LIST OF TABLES

INTRODUCTION

The purpose of this study was to examine the effects of wildfire on stream communities and their habitats in the Frank Church River of No Return Wilderness, for use in resource management. The study involved streams in the Big Creek and Middle Fork Salmon River drainages. Research in the Big Creek drainage focused on streams in which 50% or more of their watersheds burned in the 1988 Golden Fire. In particular, the ecological attributes of Cliff, Cougar, Goat, and Dunce Creeks were surveyed in 1990 and compared with results obtained from Cliff Creek in 1988 (both before and after fire) and 1989. In addition, several unburned reference streams within the Big Creek drainage were surveyed to provide comparisons with the burned sites. Further, the ecological attributes of Doe Creek, which burned in 1939, were examined to determine conditions after 50 years of recovery.

Research on Middle Fork tributaries in 1990 focused on streams in watersheds which burned in the 1988 Battle Axe Fire, for which we have several years of prefire data. These were Teapot, Pungo, and East Fork Indian Creeks. The same variables were measured in these streams as for the streams in the Big Creek area.

METHODS

Methods used for the three studies described in this report are summarized in Table 1. These are relatively routine in stream ecology and are described in detail in standard reference sources (Weber 1973, Greeson et al. 1977, Lind 197[illegible], Merritt and Cummins 1984, APHA 1990) or in more specific references listed in Table 1. Methods for sampling macroinvertebrates are described in Platts et al. (1983). Procedures for sample analysis also are described in Table 1. Macroinvertebrates were examined in terms of total numbers, total biomass, species richness, Simpson's Index, and Shannon's Diversity (H'). In addition, the top ten taxa by relative abundance were examined for all three studies.

Big Creek Study - July 1990

One objective of the this investigation was to compare conditions in streams impacted by the Golden Fire of September 1988 to those in reference streams (i.e. streams within the same drainage basin, of comparable size and aspect, not impacted by this fire)(Figure 1). Four streams were selected for study which flowed within the fire perimeter: Goat, Dunce, Cougar, and Cliff Creeks. Two reference sites were located on Cave Creek. One was located about 100 m upstream of the mouth, and the other was located on West Fork Cave Creek about 100 m upstream of the confluence with East Fork Cave Creek. Two other potential reference sites were located on Pioneer Creek, but since they drained north-facing slopes unlike all of the other streams, the data has not been processed and is not included in this report. An additional study site was located on Doe Creek whose watershed burned in 1939.

Table 1. SUMMARY OF VARIABLES, SAMPLING METHODS, AND ANALYTICAL PROCEDURES FOR EVALUATING THE EFFECTS OF WILDFIRE ON STREAM ECOSYSTEMS

VARIABLE	SAMPLE TYPE	SAMPLING METHOD	ANALYTICAL METHOD	REFERENCE
A. Physical				
1. Temperature (°C)	P	Maximum Minimum recording thermometers.	Direct Observation	
2. Discharge (m^3/s)	T	Velocity-depth profiles	Calculation: $Q=W \cdot D \cdot V$; where W=width, D=mean depth, and V=velocity.	Bovee and Milhous 1978
Width (0.1m)	P	Nylon-reinforced meter tape.	Determine width of water and bankful width.	Buchanan and Somers 1969
Depth (0.1m)	T	Meter stick.	Determine water and bankful depths at sufficient intervals to give a good estimate of the mean. No more than 10% of flow should pass between measurements.	
Velocity (0.1m/s)	T	Small Ott C-1 current meter.	Determine velocities at 0.6 x depth (from the surface) at sufficient intervals to give a good estimate of the mean. No more than 10% of the flow should pass between measurements. Estimate bankful velocities from Manning's equation.	Gregory and Walling 1973
3. Channel Gradient (%)	P	Inclinometer.	Measure water surface elevations over extended (150m) lengths upstream and downstream of the discharge transect.	
4. Substrate Particle Size	R	Select 100 rocks at random, measure L, W, and D axes	Calculate mean volume , median diameter, CV's, distributions	Leopold 1970
5. Embeddedness	R	Ocular, adjacent to previously mentioned 100 rocks.	Optical determination of degree of embeddeness by silt and sand	Platts et al. 1983
B. Chemical	P	"Grab" samples from center of stream.		
1. Alkalinity (mg/l)			Gran (in waters <40mg/l alkalinity) or methyl orange titration.	Talling 1973 APHA 1989
2. Hardness (mg/l)			EDTA titration.	APHA 1989
3. Specific Conductance (µmhos)		Determine in the field.	Temperature compensated portable YSI meter. Estimate total dissolved solids using standard conversion factor.	APHA 1989
C. Biological				
1. Periphyton	P/R	Collect samples from five separate cobblestones. Remove material from known area. Brush and rinse three times following prescribed technique. Collect material from each rock on a separate pre-combusted, tared, glass fiber filter (Whatman GFF).	Acetone extraction of chlorophyll followed by spectro-photometric assay with correction for phaeopigments. Recombine acetone with sample and evaporate to dryness. Determine AFDM as described below	Stockner and Armstrong 1971 Lorenzen 1966
2. Benthic Invertebrates	P/R	Surber sampler fitted with 250 µm mesh net. Collect 5 samples per site in proportion to principal habitat types. Disturb substratum to depth of 10cm, remove all organic matter from larger inorganic particles, preserve in 5% formalin.	Separate invertebrates by species, count, dry at 60°C, and weigh. Determine population densities and biomass, species richness, dominance, diversity, and functional feeding group composition.	Platts et al. 1983 Merritt and Cummins 1984
3. Benthic organic matter	P/R	Recover from Surber samples described above.	Estimate percent composition of various plant components (including charcoal) dry at 60°C, ash at 550°C, determine total AFDM.	

P = point sample
R = random throughout a defined lineal reach
T = transect across stream

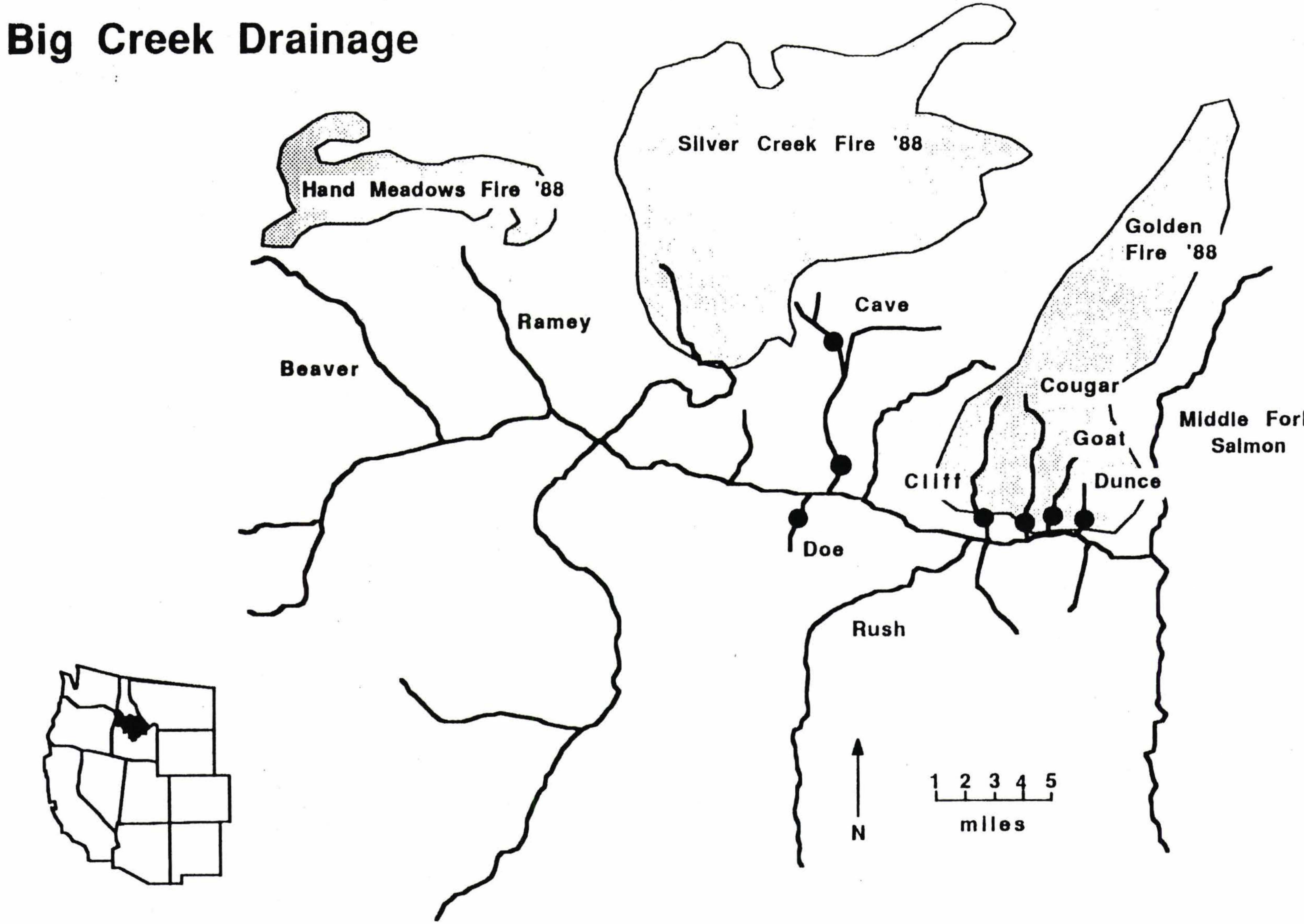


Figure 1. Site locations for the Big Creek Study 1990.

Cliff Creek Temporal Study

We completed a temporal study on Cliff Creek, a tributary of Big Creek, with samples collected in July 1988 (prefire samples), and November 1988, July 1989, and July 1990 (postfire samples). All samples were collected from the same study reach along Cliff Creek. The study section was located just upstream of the (upper) Big Creek trail crossing and about 200 m upstream of the stream mouth. We felt it important that postfire samples be collected in the same proximity to prefire samples although this location was not within the actual fire perimeter.

Mortar Creek Study

The Battle Axe fire of 1988 provided the opportunity to analyze prefire and postfire benthic samples from the same stream. The Battle Axe fire burned the watersheds of Indian, Pungo, and Teapot Creeks. These streams had acted as reference sites to streams impacted by the Mortar Creek fire of 1979, thus providing both prefire and postfire data. Because of the remote location of these sites, we also took the opportunity to collect benthic samples from other study streams used for the Mortar Creek fire study, and have included data from Little and Little Loon Creeks in the present report.

RESULTS

Big Creek Study - July 1990

Chemical and Physical Measurements: Comparisons were made among four burn streams (Goat, Dunce, Cougar, and Cliff Creeks), two reference streams (West Fork Cave Creek, and Main Cave Creek at the mouth), and Doe Creek (a watershed impacted by fire in 1939. Baseflow discharge ranged from 0.01-0.32 m^3/s among the burn streams; it was 0.01 and 0.31 m^3/s for the reference streams and 0.02 m^3/s for Doe Creek (Table 2). Ionic concentrations were highest at WF Cave and lowest at Main Cave Creek (Table 2). Overall, concentrations at Goat and Dunce Creeks compared most closely with those of WF Cave Creek, while values at Cougar, Cliff, and Doe Creeks were close to, but somewhat higher, than those of Main Cave Creek. The pH ranged from 8.1 to 8.5 in the burn streams, compared to 7.9 and 8.0 for the reference sites. The burn sites tended to have higher stream temperatures (around 11 ^oC) than the reference site of WF Cave (at 9.0 ^oC), while the Main Cave Creek site displayed the highest stream temperature at 15.0 ^oC (Table 2). The higher temperature at the Main Cave Creek site is not surprising because this stream flows for about 5 km through a long broad valley, with a relatively open canopy, upstream of the sample site.

No major differences were observed in channel morphology (using the ratio of high/low channel cross-sectional area) among burn and reference streams, although Doe Creek displayed the highest H/L ratio value (Table 3). This higher H/L ratio value may reflect the heavy riparian growth along Doe Creek

Table 2. Water chemistry, flow data, and temperature for burn and reference streams in the Big Creek drainage, July 1990.

STREAM	TYPE	Q (m^3/s)	ALKALINITY (mg/L CaCo3)	TOTAL HARDNESS (mg/L CaCo3)	pH	SPECIFIC CONDUCTANCE (umhos)	TEMP (C)
GOAT	BURN	0.01	86.0	110.0		139	12.5
DUNCE	BURN	0.02	76.0	100.0	8.3	129	12.6
COUGAR	BURN	0.11	46.0	71.0	8.5	70	11.0
CLIFF	BURN	0.32	35.0	66.0	8.2	61	12.8
WF CAVE	REFERENCE	0.01	134.0	161.0	8.0	177	9.0
MTH CAVE	REFERENCE	0.31	24.0	44.0	7.9	39	15.0
DOE	50 YR BURN	0.02	51.0	65.0	8.1	76	10.0

Table 3. Physical data for burn and reference streams in the Big Creek drainage, July 1990.

STREAM	TYPE	AREA H/L	SUBSTRATE LENGTH			SUBSTRATE EMBEDDEDNESS		
			MEAN	STD	CV	MEAN	STD	CV
GOAT	BURN	1.48	9.7	16.6	1.72	74.8	36.5	0.49
DUNCE	BURN	1.73	21.3	29.3	1.40	63.0	37.0	0.59
COUGAR	BURN	1.55	21.6	13.3	0.62	21.2	26.6	1.25
CLIFF	BURN	1.30	25.3	18.7	0.74	32.5	33.3	1.02
WF CAVE	REFERENCE	1.51	4.1	4.7	1.12	44.8	44.3	0.99
MTH CAVE	REFERENCE	1.39	18.8	12.2	0.65	17.5	27.5	1.57
DOE	50 YR BURN	2.12	14.7	14.8	1.00	20.0	28.7	1.44

causing subsurface flow at many locations. Some differences are evident in mean substrate size and the coefficient of variation (CV) of substrate size among the study streams, with the smaller streams having smaller substrate sizes and greater CV's. For example, the mean substrate size of Goat Creek was comparable to WF Cave Creek, and mean substrate size in both was markedly smaller (> 2X) than the remaining sites. In addition, substrate CV's of Goat and Dunce Creeks were comparable to WF Cave Creek, while substrate CV's at Cougar and Cliff Creeks were comparable to the CV value at Main Cave Creek (Table 3). The latter sites displayed about half the variability of the former in substrate composition. Doe Creek had values of mean substrate size and substrate CV intermediate between the two groups. Further, the pattern of response for substratum CV's matched that for water chemistry.

Mean embeddedness (as %) was substantially greater in the burn streams than in the similarly-sized reference stream. For example, embeddedness values at Goat and Dunce Creeks were most similar, although higher, to WF Cave Creek. Further, embeddedness values at Cougar and Cliff Creeks were most similar, although somewhat higher, to Main Cave Creek. The former (smaller) streams had embeddedness values 2-3X greater than the latter (larger) streams. Doe Creek (the 50 year burn site) had embeddedness values more similar to the same size reference stream than to the same size burn streams (Table 3). Embeddedness values at Doe Creek were most similar to values at the larger size Cougar, Cliff, and Main Cave Creeks. Embeddedness CV's followed this same trend, but were lowest in the most embedded streams and highest in the least embedded streams.

Periphytic and Benthic Organic Matter: Periphyton chlorophyll a levels were lower in all burn sites than in reference sites except for Goat Creek (Figure 2). Doe Creek displayed chlorophyll a values comparable to values found in reference sites. The AFDM of periphyton indicated similar values between small burn streams and the respective reference stream, and lower AFDM values for the larger burn sites relative to the reference stream. The periphyton AFDM values at Doe Creek were comparable to the reference sites. The B/C index, an index of relative autotrophy (APHA 1989), was substantially greater in Dunce and Cougar Creeks (burn sites), than other study sites and may reflect the relative burn intensity at these sites in creating a more open canopy (Figure 2). The B/C ratio at Doe Creek was similar to values found at the reference sites, while Goat and Cliff Creeks showed lower B/C ratio values and may reflect greater riparian cover at these sites.

The mean quantity of benthic organic matter was greater in Goat Creek (about 16 g/m^2) than any other stream site (all less than 7 g/m^2)(Figure 3). In fact, all other study sites had essentially the same amount of organic matter present. The % charcoal of this organic matter followed the same pattern, with Goat Creek having a substantially greater charcoal content (about 40% charcoal) than the other study sites (Figure 3). The other study streams all displayed low levels of % charcoal with values usually being less than 20%.

Macroinvertebrate Community Analysis: Average total biomass of macroinvertebrates was about 2X greater in the reference streams than in the burn streams, being about 1000 mg/m^2 in the reference streams (Figure 4). Doe

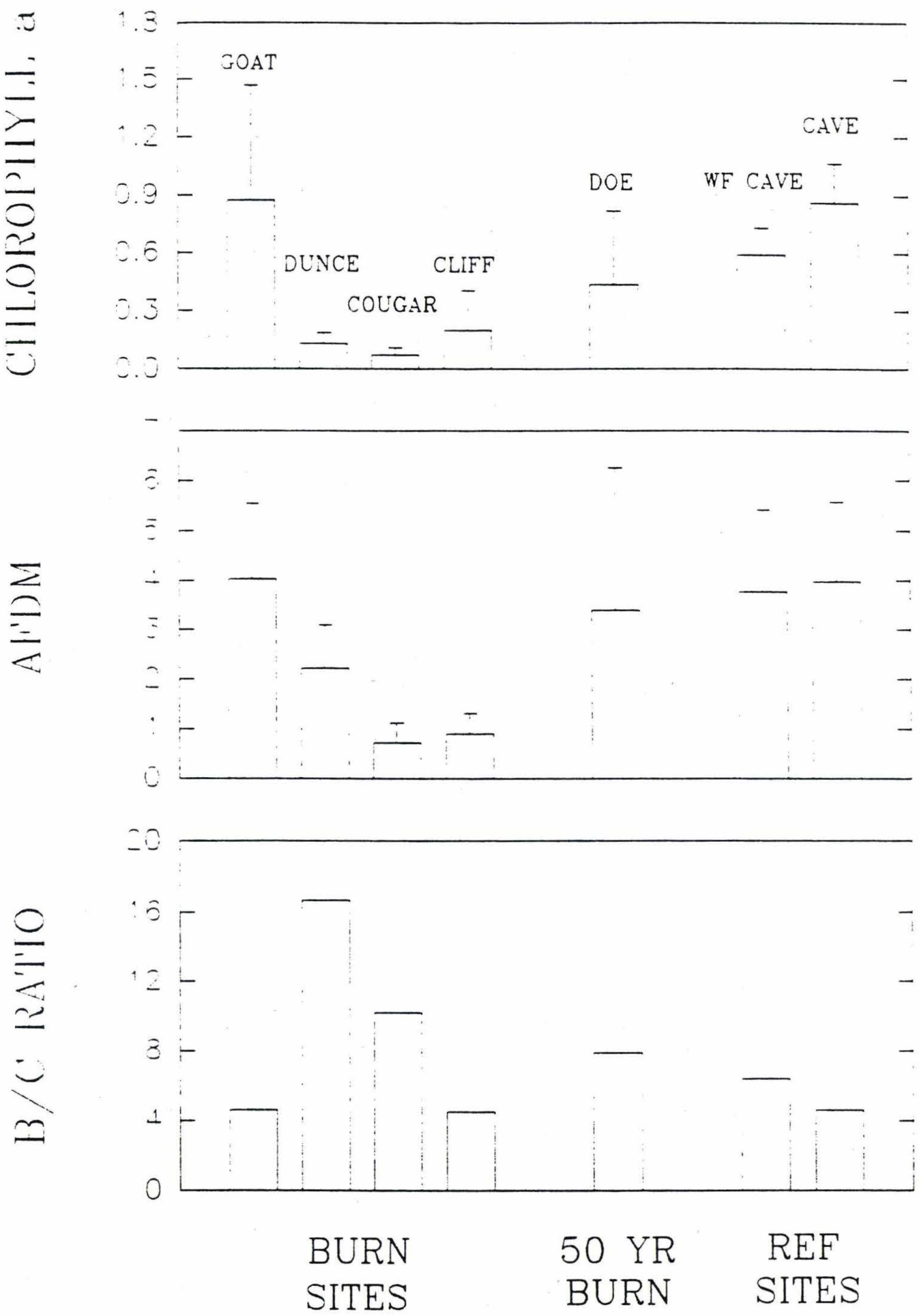


Figure 2. Periphyton chlorophyll a (ug/m2), AFDM (g/m2), and Biomass/Chlorophyll Ratio (B/C) for study streams in the Big Creek Drainage in 1990. Bars represent +1 SD.

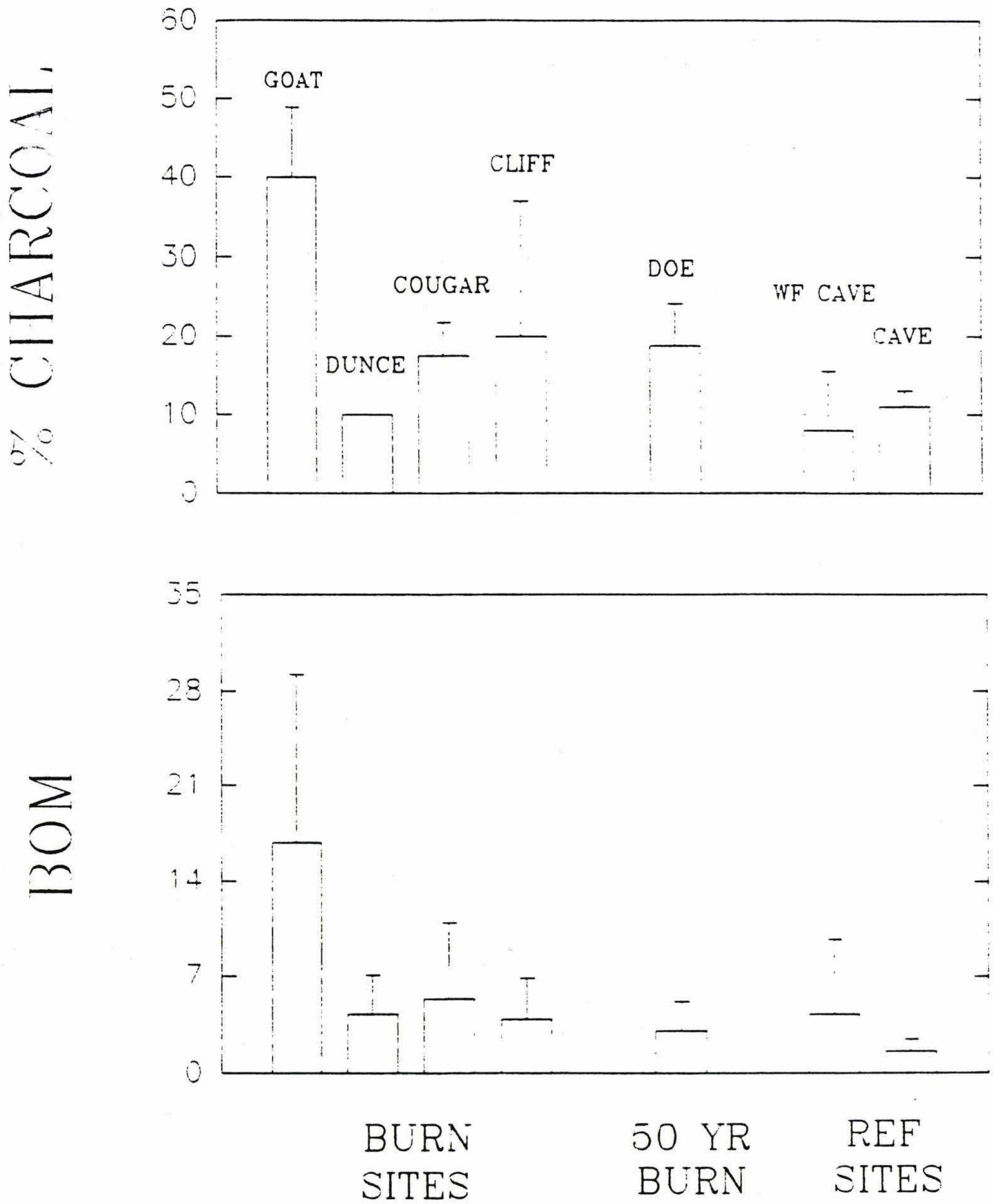


Figure 3. The quantity of benthic organic matter (g/m2), and % charcoal of BOM for study streams in the Big Creek Drainage in 1990. Bars represent +1 SD.

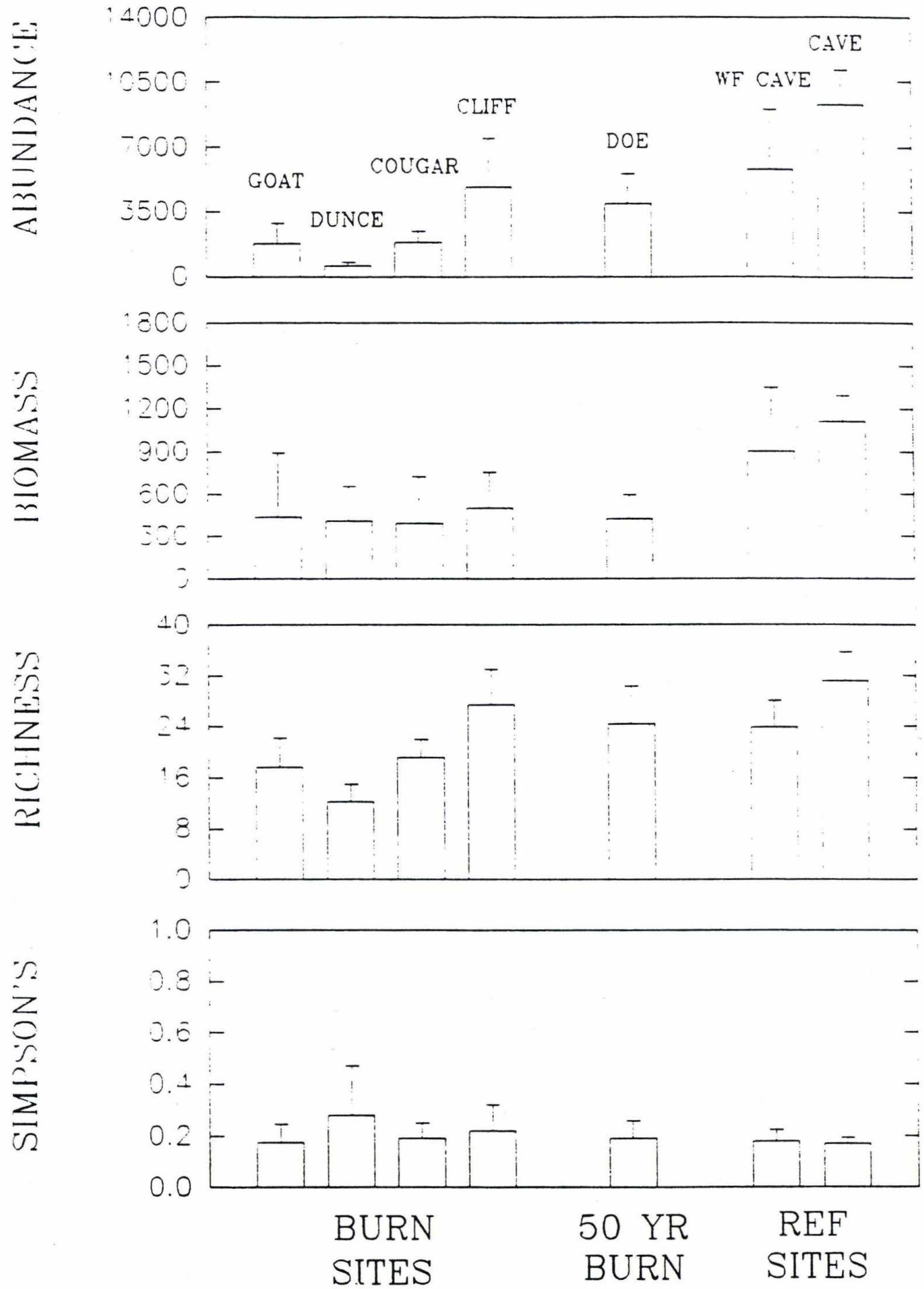


Figure 4. Mean macroinvertebrate abundance (#/m2), biomass (mg/m2), species richness, and Simpson's Index for study streams in the Big Creek Drainage for 1990. Bars represent +1 standard deviation.

Creek displayed mean biomass values similar to those found in the 2-year burn streams. As with mean biomass, the average abundance of macroinvertebrates was substantially greater in the reference sites compared to the 2-year burn streams, except for Cliff Creek (Figure 4). Doe Creek had abundance values similar to those found in Cliff and WF Cave Creeks.

Macroinvertebrate species richness was lower in all of the 2-year burn sites, except Cliff Creek, compared to the reference sites (Figure 4). Cliff and Doe Creeks displayed richness values comparable to those found in Main Cave Creek. No marked differences were observed in Simpson's Index (an index of dominance) among the stream sites, although Dunce Creek showed the highest value (Figure 4). The relatively low Simpson's Index values displayed at all sites indicates a high degree of taxa evenness within a site.

Macroinvertebrate Taxa Analysis: The ten most abundant taxa comprised over 80% of the community assemblage at a site (Table 4). There were five taxa common to all sites: Chironomidae, the elmid <u>Heterlimnius</u>, Oligochaeta, Ostracoda, and the plecopteran <u>Suwallia</u>. The Hydracarina, a predatory mite, was rare in all burn sites except Goat Creek, but was present in the top ten taxa in the reference sites and Doe Creek comprising 1.5-7 % of the assemblage. Another predator, <u>Ryacophila vespula</u> was found in Doe Creek and WF Cave Creek, but was not observed in burn streams (Table 4). The dipteran, Ceratopogonidae, was present in smaller burn sites, comprising 12.3% in Dunce Creek. Ceratopogonidae was absent from the top ten taxa in the reference sites and in Doe Creek. The highly mobile mayfly, <u>Baetis</u>, was most abundant in burn sites, comprising over 15% of the assemblage in Cougar and Cliff Creeks. <u>Baetis</u> was found in Main Cave Creek, comprising less than 6% of the macroinvertebrate assemblage, while being rare in WF Cave and Doe Creeks. This suggests that the high chlorophyll <u>a</u> level at Main Cave Creek may be due to reduced grazing pressure by <u>Baetis</u>. Blackflies, <u>Simulium</u>, constituted 3-6% of total abundance in all burn streams, except Cougar Creek, and were relatively more abundant in the burn streams than in reference streams (Table 4). <u>Simulium</u> are filter feeders, and their increased abundance in the burn streams may indicate higher levels or quality of microseston. Mean abundance and biomass of individual taxa for each stream studied are found in Appendices 1 and 2, respectively.

Cliff Creek Temporal Analysis - 1988, 1989, 1990

Periphytic and Benthic Organic Matter: Periphyton samples were collected in prefire 1988 and postfire 1990 only. There was no difference in chlorophyll <u>a</u> levels between 1988 and 1990 (Figure 5). The ash-free-dry-mass (AFDM) of periphyton was about 2X higher in 1988 than in 1990, although the standard deviation in 1988 made this result nonsignificant from the 1990 result. The mean AFDM prefire value for 1988 in Cliff Creek also was less than reference levels found at Cave Creek in 1990 (see Figure 2).

The average quantity of benthic organic matter (BOM) was lower in 1989 than in 1988 or 1990 (Figure 6). The % charcoal of the BOM tended to increase from 1988 to 1990, increasing from about 10% in 1988 to over 20% in 1990. These data suggest that charcoal is being transported from upstream sources

Table 4. Absolute and relative macroinvertebrate abundance (#/m2) of top ten taxa for burn and reference streams in the Big Creek drainage, July 1990.

GOAT — BURN

taxa	Absolute MEAN	Absolute SD	Relative (%)
Ostracoda	463.1	425.6	26.1
Heterlimnius sp.	303.0	280.7	17.1
Chironomidae	143.0	137.0	8.1
Simulium pupae	106.7	193.4	6.0
Oligochaeta	91.8	52.1	5.2
Zapada cinctipes	89.6	78.6	5.0
Suwallia sp.	76.8	72.1	4.3
Ceratopogonidae	55.5	118.2	3.1
Hydracarina	49.1	38.9	2.8
Baetis bicaudatus	44.8	66.8	2.5

DOE — 50 YR BURN

taxa	Absolute MEAN	Absolute SD	Relative (%)
Ostracoda	1218.5	691.2	31.0
Heterlimnius sp.	819.5	527.8	20.9
Suwallia sp.	411.9	189.8	10.5
Chironomidae	283.8	292.1	7.2
Cinygmula sp.	136.6	110.2	3.5
Oligochaeta	106.7	124.2	2.7
Simulium	102.4	84.6	2.6
Rhyacophila vespula	96.0	79.5	2.4
Hydracarina	79.0	55.8	2.0
Yoroperla brevis	74.7	42.7	1.9

DUNCE — BURN

taxa	Absolute MEAN	Absolute SD	Relative (%)
Yoroperla brevis	79.0	389.0	13.4
Ceratopogonidae	72.6	144.6	12.3
Heterlimnius sp.	68.3	84.6	11.6
Narpus sp.	57.6	101.7	9.7
Zapada cinctipes	57.6	99.7	9.7
Chironomidae	46.9	44.4	7.9
Oligochaeta	42.7	27.2	7.2
Suwallia sp.	36.3	24.6	6.1
Simulium pupae	23.5	20.5	4.0
Baetis bicaudatus	19.2	20.5	3.2

WF CAVE — REFERENCE

taxa	Absolute MEAN	Absolute SD	Relative (%)
Ostracoda	1568.5	685.9	27.0
Heterlimnius sp.	1124.6	699.0	19.3
Chironomidae	917.6	1187.6	15.8
Yoroperla brevis	757.6	293.5	13.0
Oligochaeta	262.5	318.8	4.5
Rhyacophila vespula	157.9	85.5	2.7
Nematoda	134.4	236.4	2.3
Suwallia sp.	119.5	95.2	2.1
Paraleptophlebia sp.	89.6	88.2	1.5
Hydracarina	79.0	50.4	1.4

COUGAR — BURN

taxa	Absolute MEAN	Absolute SD	Relative (%)
Heterlimnius sp.	593.3	382.8	32.1
Baetis bicaudatus	315.8	239.6	17.1
Chironomidae	245.4	149.2	13.3
Heptageniidae	85.4	115.9	4.6
Suwallia sp.	72.6	23.1	3.9
Oligochaeta	70.4	50.9	3.8
Zapada cinctipes	64.0	66.2	3.5
Ostracoda	51.2	37.3	2.8
Hexatoma sp.	49.1	49.2	2.7
Neophylax sp.	49.1	48.7	2.7

MTH CAVE — REFERENCE

taxa	Absolute MEAN	Absolute SD	Relative (%)
Oligochaeta	2161.7	642.1	23.2
Heterlimnius sp.	2114.8	1062.2	22.7
Chironomidae	1449.0	434.6	15.6
Ostracoda	744.8	759.4	8.0
Hydracarina	623.1	446.4	6.7
Baetis intermedius	537.8	302.0	5.8
Suwallia sp.	243.3	218.5	2.6
Isoperla sp.	236.9	129.0	2.5
Chironomidae pupae	234.7	110.9	2.5
Serratella tibialis	106.7	43.3	1.1

CLIFF — BURN

taxa	Absolute MEAN	Absolute SD	Relative (%)
Chironomidae	864.3	1274.7	17.8
Baetis bicaudatus	723.4	721.0	14.9
Oligochaeta	706.4	796.3	14.5
Heterlimnius sp.	672.2	369.7	13.8
Suwallia sp.	326.5	350.1	6.7
Cinygmula sp.	202.7	249.3	4.2
Simulium	155.8	194.7	3.2
Ostracoda	151.5	46.1	3.1
Baetis intermedius	140.8	309.0	2.9
Chironomidae pupae	136.6	108.7	2.8

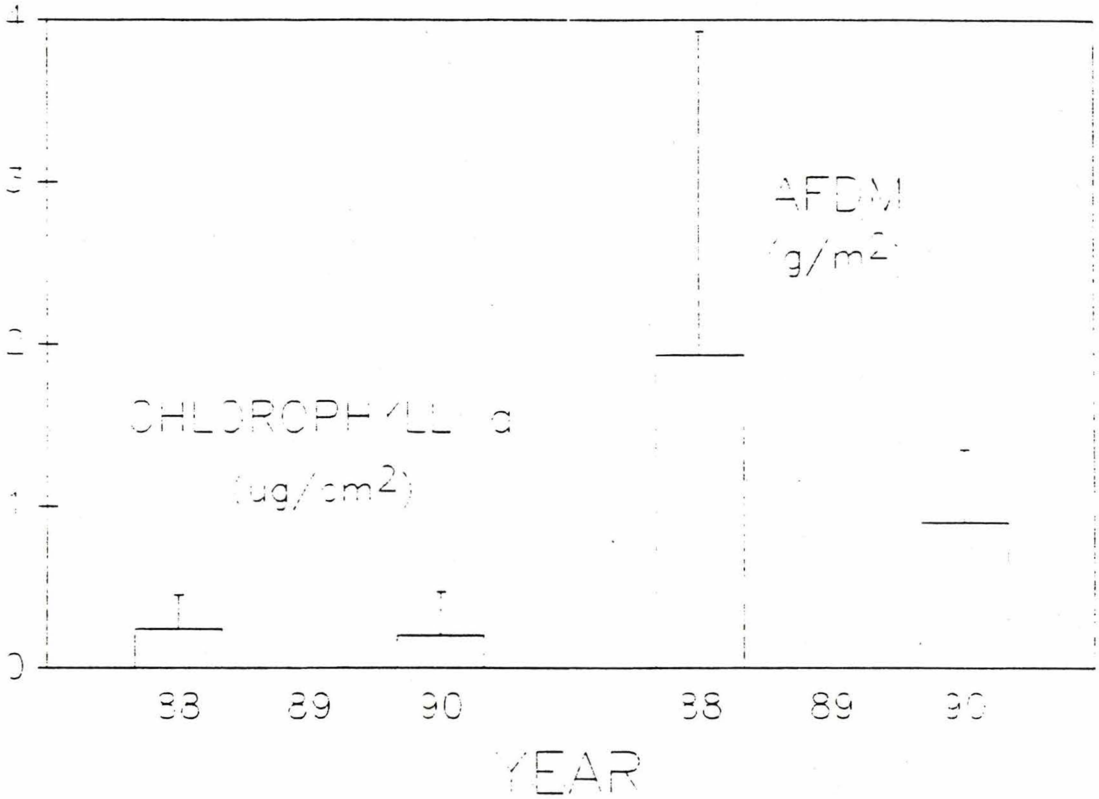


Figure 5. Periphyton chlorophyll a and biomass (as AFDM) for Cliff Creek in 1988, 1989, and 1990. Bars represent one standard deviation from the mean.

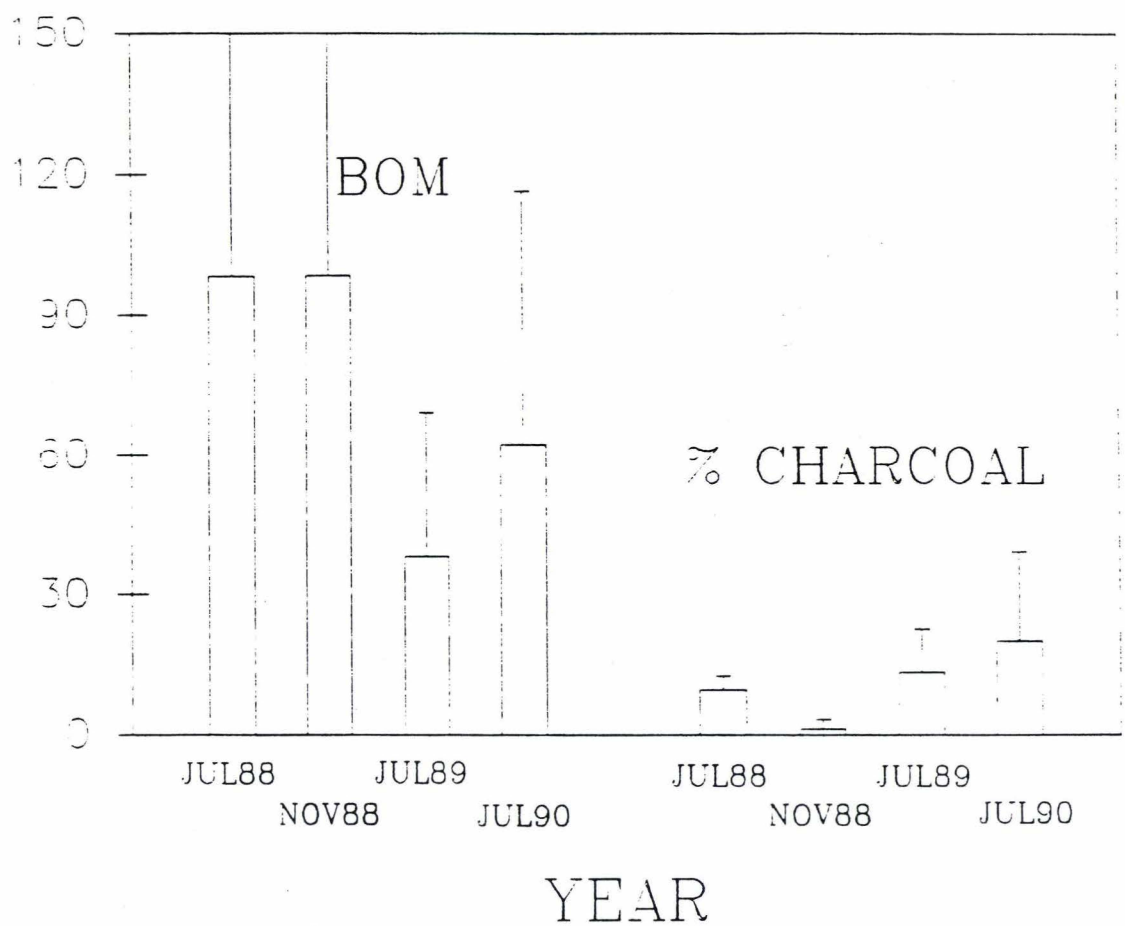


Figure 6. Benthic organic matter (mg/m2) and percent charcoal of BOM for Cliff Creek in 1988, 1989, and 1990. Bars represent +1 standard deviation from the mean.

and being retained within the study area over time.

Macroinvertebrate Community Analysis: The abundance of macroinvertebrates increased in November 1988 immediately after the fire, then decreased dramatically in 1989 (Figure 7). Mean abundance increased in 1990, although mean abundance was still lower than preburn values but similar to values found in Cave Creek in 1990 (see Figure 4). No differences were observed in mean biomass values among sampling dates, and held around 500 mg/m^2 throughout the study (Figure 7).

Species richness was higher in November than July 1988 probably reflecting normal seasonal differences. However, species richness remained around 25 taxa for all prefire and post-fire July samples (Figure 8). These values also were similar to those found at both reference sites (Cave Creek) in 1990 (see Figure 4). Simpson's Index values remained essentially unchanged, although a slight decrease was observed in July 1990 (Figure 8). Again, a low Simpson's Index indicates a more even distribution among taxa within an assemblage.

Macroinvertebrate Taxa Analysis: The top ten taxa, by relative abundance, comprised over 80% of the assemblage in July 1988, 1989, and 1990 (Table 5). Seven of these ten taxa were found on all sample dates: Alloperla, Baetis, Chironomidae, Cinygmula, Heterlimnius, Oligochaeta, and Ostracoda. Baetis, Chironomidae, and Heterlimnius increased in absolute and relative abundance from 1988 through 1990, whereas the relative abundance of Cinygmula, and Oligochaeta decreased. The absolute and relative abundances of Alloperla and Ostracoda remained unchanged among sampling dates (Table 5). Glossosoma comprised about 10% of the fauna in 1989, while being rare in both 1988 and 1990. Because Glossosoma is a scraper grazer, these results suggest that chlorophyll a values may have been lower in 1989 than in the two adjacent years (see Figure 5). Simulium was observed in the top ten taxa for 1988 and 1990, but was rare in 1989. A total of 95 taxa were identified from Cliff Creek, with their abundance and biomass found in Table 6.

Mortar Creek Study - 1990

Physical and Chemical Characteristics: Five sites from the Mortar Creek Fire study were analyzed to compare changes between 1980 and 1990: Teapot, EF Indian, Pungo, Little, and Little Loon Creeks. The watersheds of Little and L. Loon Creeks were burned in 1979 (Mortar Creek Fire), while those of Teapot, EF Indian, and Pungo Creeks burned in 1988 (Battle Axe Fire). The former streams were not impacted in the Battle Axe Fire, while the latter streams were not impacted in the Mortar Creek Fire.

No major changes occurred in alkalinity levels between 1980 and 1990 for any stream, although total hardness increased by about 20 mg/L $CaCO_3$ (Table 7). Alkalinity and total hardness generally were low, being less than 70 mg/L $CaCO_3$ for alkalinity and less than 80 mg/L $CaCo_3$ for total hardness.

Channel profiles were compared for 1987 and 1990 for all sites except L. Loon Creek where the 1984 profile was used in place of 1987 because of transect misplacement from 1985-1987. Profiles are displayed in a downstream

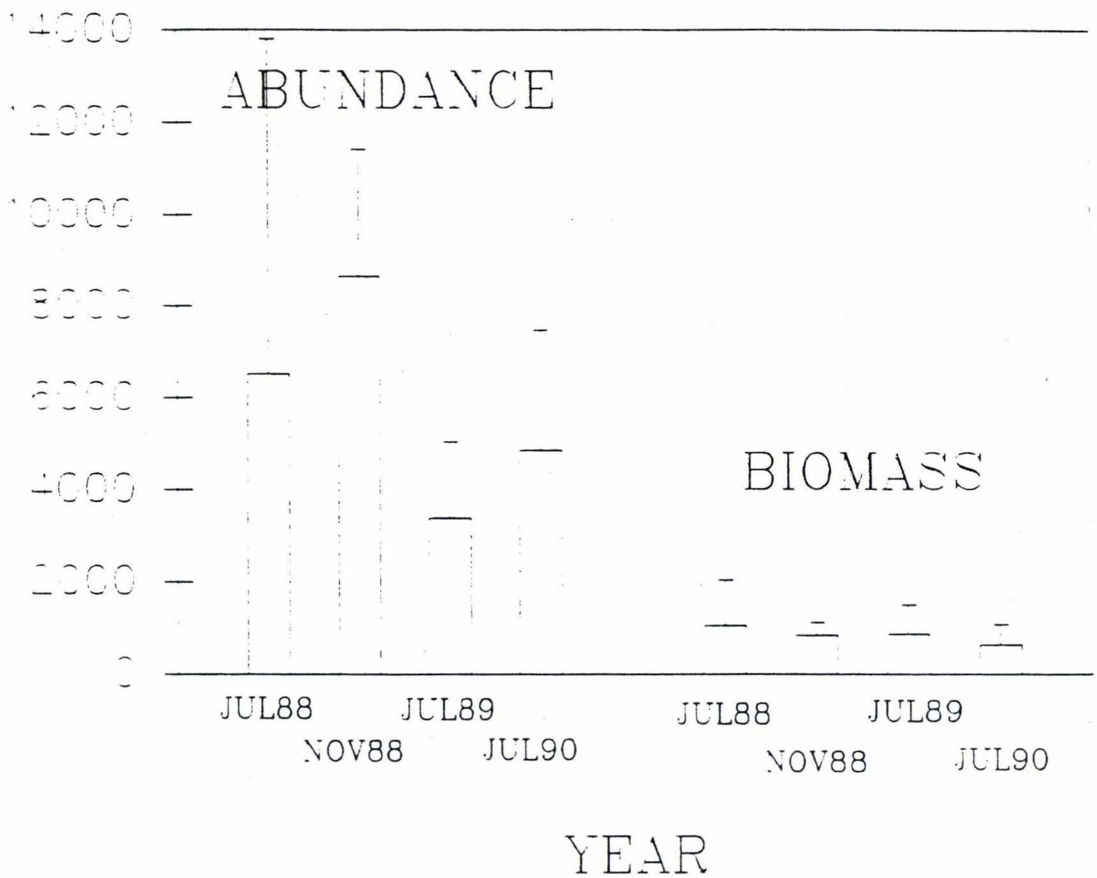


Figure 7. Mean abundance (#/m2) and biomass of macroinvertebrates for Cliff Creek in July 1988, November 1988, July 1989, and July 1990. Bars represent one standard deviation from the mean

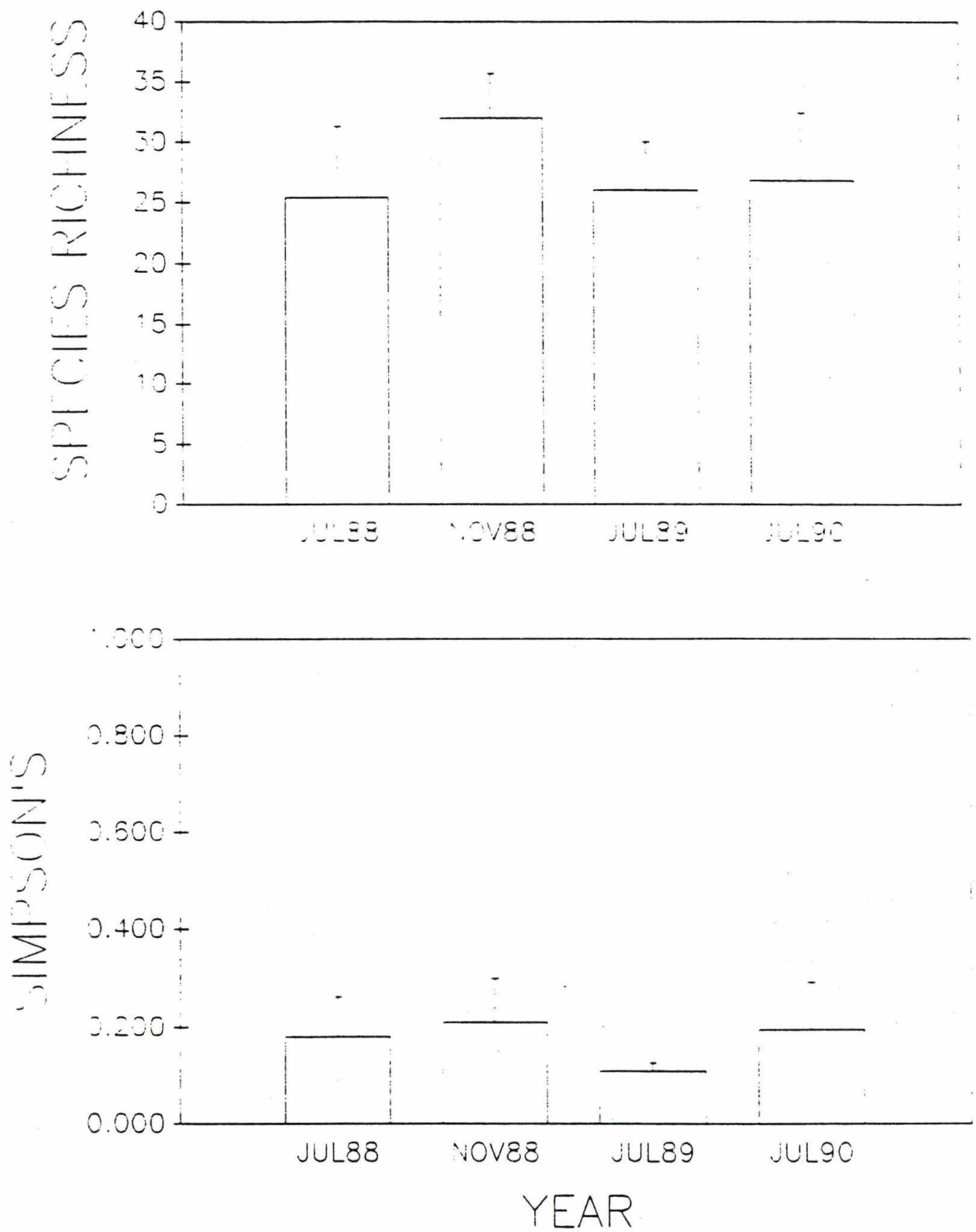


Figure 8. Macroinvertebrate species richness and Simpson's Index for Cliff Creek in 1988, 1989, and 1990. Bars represent one standard deviation from the mean.

Table 5. Absolute and relative macroinvertebrate abundance of top ten taxa for 1988, 1989, and 1990 in Cliff Creek.

	ABUNDANCE (#/m2)				ABUNDANCE (#/m2)				ABUNDANCE (#/m2)		
July 1988	ABSOLUTE		RELATIVE	July 1989	ABSOLUTE		RELATIVE	July 1990	ABSOLUTE		RELATIVE
	MEAN	SD	(%)		MEAN	SD	(%)		MEAN	SD	(%)
Oligochaeta	2116.9	2619.3	32.1	Chironomidae	448.1	385.1	13.2	Chironomidae	864.3	1274.7	17.9
Cinygmula sp.	617.8	334.9	9.4	Heterlimnius	409.5	282.0	12.1	Baetis bicaudatus	723.4	721.0	14.9
Polycentropus sp.	434.3	1347.1	6.6	Baetis bicaudatus	334.8	269.3	9.9	Oligochaeta	706.4	796.3	14.6
Heterlimnius sp.	387.3	410.7	5.9	Glossosoma sp.	328.1	291.9	9.7	Heterlimnius	672.2	369.7	13.9
Chironomidae	353.2	476.6	5.4	Oligochaeta	290.8	292.0	8.6	Suwallia	326.5	350.1	6.7
Suwallia	345.7	351.5	5.3	Suwallia	264.1	157.8	7.8	Cinygmula sp.	202.7	249.3	4.2
Baetis bicaudatus	312.6	457.4	4.8	Cinygmula sp.	229.4	104.5	6.8	Simulium	155.8	194.7	3.2
Simulium	284.9	771.6	4.4	Ostracoda	189.4	102.5	5.6	Ostracoda	151.5	46.1	3.1
Nematoda	275.3	833.2	4.2	Ephemerella infreq	144.0	109.9	4.3	Baetis intermedius	140.8	309.0	2.9
Ostracoda	273.2	863.8	4.2	Zapada sp.	132.0	179.7	3.9	Chironomidae pupae	136.6	108.7	2.8

Table 6. Absolute abundance and biomass of individual taxa for Cliff Creek in July 1988, July 1989, and July 1990.

	ABUNDANCE (#/m2)						BIOMASS (mg/m2)					
	1988		1989		1990		1988		1989		1990	
PREDATORS	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std
Ceratopogonidae	35.2	53.7	26.7	37.0	4.3	9.5	4.4	8.8	3.2	4.2	0.2	0.4
Chelifera sp.	2.1	4.5			38.4	35.9	0.1	0.2			3.1	3.6
Chloroperlidae					44.8	100.2					1.2	2.6
Diapriidae			1.3	3.8					0.1	0.4		
Dicronota sp.	2.1	6.7	18.7	18.7			0.0	0.1	1.1	1.3		
Doroneuria sp.			1.3	3.8					0.8	2.4		
Empididae	1.1	3.4					0.0	0.1				
Glutops sp.					6.4	9.5					12.0	16.5
Hydracarina	10.7	10.1	24.0	18.7	51.2	48.5	0.5	0.8	0.8	0.7	1.1	1.2
Hydracarina sp. 2					12.8	17.5					0.4	0.4
Isoperla sp.			2.7	4.9					0.3	0.5		
Limnophila sp.			2.7	7.5					0.7	2.0		
Limoniinae					2.1	4.8					0.1	0.3
Limoniinae pupae					2.1	4.8					4.1	9.2
Megarcys sp.	27.7	17.6	4.0	5.5			15.6	13.8	23.5	36.2		
Nematoda	275.3	833.2	36.0	39.9	121.6	214.5	1.1	2.9	0.5	0.4	1.3	1.7
Oreogeton sp.			1.3	3.8					0.1	0.2		
Perlodidae					34.1	33.2					8.3	7.9
Plecoptera	25.6	81.0					0.3	0.8				
Rhyacophila sp.												
angelita	69.4	112.4	25.3	31.7	2.1	4.8	3.0	4.8	2.9	3.8	0.2	0.4
bifila					6.4	9.5					39.1	54.0
rotunda	48.0	82.5					2.6	4.6				
vaccua			1.3	3.8					0.6	1.7		
vagrita			16.0	19.8	17.1	20.8			0.7	1.1	0.5	0.5
vespula			4.0	11.3	27.7	34.2			1.5	4.4	1.6	1.6
Stenus sp.			1.3	3.8					0.7	1.8		
Suwallia sp.	345.7	351.5	264.1	157.8	326.5	350.1	50.7	50.6	48.9	30.4	17.9	18.7
Tipulidae					4.3	5.8					0.3	0.4
Coleoptera larvae					2.1	4.8					0.2	0.4
Diptera adult					2.1	4.8					0.3	0.7
Turbellaria	40.5	65.2	5.3	11.4			14.4	23.1	2.8	5.8		
GATHERERS												
Ameletus sp.												
velox	4.3	9.0					0.4	0.8				
Ampumixis sp.	5.3	10.4					19.2	44.5				
Antocha sp.	4.5	7.5	6.7	18.9			0.0	0.1	0.6	1.8		
Apatania sp.	36.3	34.2	4.0	7.9			0.8	1.8	0.9	2.3		
Capniidae	5.3	9.1			6.4	14.3	0.3	0.6			0.3	0.7
Collembola			6.7	12.7	2.1	4.8			0.1	0.2	0.0	0.1
Ecclisiomyia sp.	1.1	3.4	1.3	3.8			0.0	0.1	1.1	3.2		
Ephemerella sp.	17.1	54.0	13.3	14.8			0.1	0.3	1.2	1.6		
Hemerodromia sp.			1.3	3.8	4.3	9.5			0.1	0.2	0.1	0.2
Heterlimnius sp.	387.3	410.7	410.0	282.0	672.2	369.7	24.3	24.3	32.0	17.0	72.5	48.7
Heterlimnius adult	10.7	14.2					2.6	3.6				
Moselyana sp.					12.8	28.6					0.1	0.2
Paraleptophlebia sp.	141.9	219.5	8.0	11.0			3.2	4.8	0.7	1.3		
Pericoma sp.			4.0	7.9					0.3	0.8		
Polycentropus sp.	434.3	1347.1					22.6	70.2				
Rhyacophila acropedes	41.6	67.8	49.3	63.5	23.5	23.1	23.4	32.8	39.0	40.1	86.6	
Serratella tibialis	42.7	70.6					14.5	24.6				
Stratiomyidae			1.3	3.8					0.5	1.4		

Table 6. (cont.)

	ABUNDANCE (#/m2)						BIOMASS (mg/m2)					
	1988		1989		1990		1988		1989		1990	
	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std
Trichoptera												
adult							0.4	0.9				
pupae							14.9	33.0				
SCRAPERS												
Baetis bicaudatus	312.6	457.4	334.8	269.3	723.4	721.0	17.3	28.5	13.0	11.3	37.8	26.1
Baetis intermedius					140.8	309.0					20.6	45.6
Cinygmula sp.	617.8	334.9	229.4	104.5	202.7	249.3	57.5	41.8	5.6	2.7	33.9	41.2
Drunella sp.												
colordensis	109.9	104.1					60.5	51.5				
doddsi			52.0	53.9	2.1	4.8	1.6	1.3	9.5	11.3	16.0	35.7
flavilinea					51.2	41.6					22.1	23.7
spinifera					2.1	4.8					6.8	15.2
Epeorus												
deceptivus			89.4	182.3	2.1	4.8			30.1	67.4	10.4	23.2
grandis					2.1	4.8					13.5	30.2
longimanus	188.9	228.4			2.1	4.8	9.7	19.5			1.0	2.2
Gastropoda					2.1	4.8					0.1	0.2
Glossosoma sp.	8.5	14.0	328.1	291.9	2.1	4.8	0.6	0.9	28.5	25.6	0.9	2.1
Glossosomatidae					2.1	4.8					1.8	4.0
Heptageniidae					10.7	13.1					0.7	1.1
Neophylax sp.	4.3	7.5	2.7	4.9	42.7	36.2	6.7	13.5	1.8	3.9	13.1	11.6
Ephemerella hystrix					6.4	14.3					3.8	8.5
Rhithrogena sp.			48.0	50.7					23.3	20.7		
SHREDDERS												
Capnia sp.	19.2	57.1	5.3	9.9			1.0	3.1	0.4	0.8		
Clostoeca sp.							0.4	1.3				
Ephemerella infrequens			144.0	109.9					18.9	44.2		
Lara sp.			1.3	3.8					0.3	0.9		
Micrasema sp.	12.8	28.8	2.7	7.5			0.5	1.1	0.5	1.4		
Tipula sp.	14.9	18.3	5.3	8.1			79.5	176.2	168.4	311.0		
Yoroperla brevis	1.1	3.4	14.7	22.0	21.3	18.5	0.1	0.3	8.0	17.3	5.7	5.7
Zapada sp.	108.8	223.0	132.0	179.7	117.4	170.4	4.8	12.1	14.3	21.8	4.7	7.1
FILTERERS												
Arctopsyche sp.	1.1	3.4					5.0	16.0				
Brachycentrus sp.					6.4	14.3					0.4	0.8
Dolophilodes			65.4	99.7					170.5	245.8		
Oligoplectrum					6.4	9.5					2.6	3.9
Ostracoda	273.2	863.8	189.4	102.5	151.5	46.1	3.6	11.3	2.2	1.6	3.4	1.7
Parapsyche elsis			22.7	26.4	2.1	4.8			170.4	274.3	78.5	175.6
Simulium	284.9	771.6	20.0	27.6	155.8	194.7	4.0	6.6	2.0	3.3	17.4	20.3
Prosimulium			5.3	15.1					0.4	1.0		
MINERS												
Chironomidae	353.2	476.6	448.1	385.1	864.3	1274.7	6.4	7.0	148.9	392.6	20.5	22.8
pupae	7.5	13.4			136.6	108.7	0.2	0.3			4.4	3.3
adult					12.8	13.9					0.5	0.7
Lumbriculus sp.	18.1	25.7					44.3	95.5				
Oligochaeta	2116.9	2619.3	290.8	292.0	706.4	796.3	33.7	49.2	22.7	22.7	32.9	50.0
OTHERS												
Amphipoda					14.9	17.9					0.1	0.1
Hymenoptera Diapriidae					2.1	4.8					0.9	2.1
Pseudoscorpion	1.1	3.4										
Tadpole	2.1	6.7					130.4	412.2				
Other terrestrials	13.9	19.5			17.1	16.2	2.2	5.2			8.4	16.4

Table 7. Alkalinity and hardness of streams in the Mortar Creek drainage for July 1980 and July 1990.

STREAM	Alkalinity (mg/L CaCO3)		Total Hardness (mg/L CaCO3)	
	1980	1990	1980	1990
TEAPOT CK.	39.3	36.5	28.8	44.5
EAST FORK INDIAN CK.	44.2	47.6	31.7	52.5
PUNGO CK.	52.8	53.9	41.4	57.7
LITTLE CK.	69.2	76.6	54.1	78.5
MOUTH LITTLE LOON	55.8	57.4	37.4	52.9

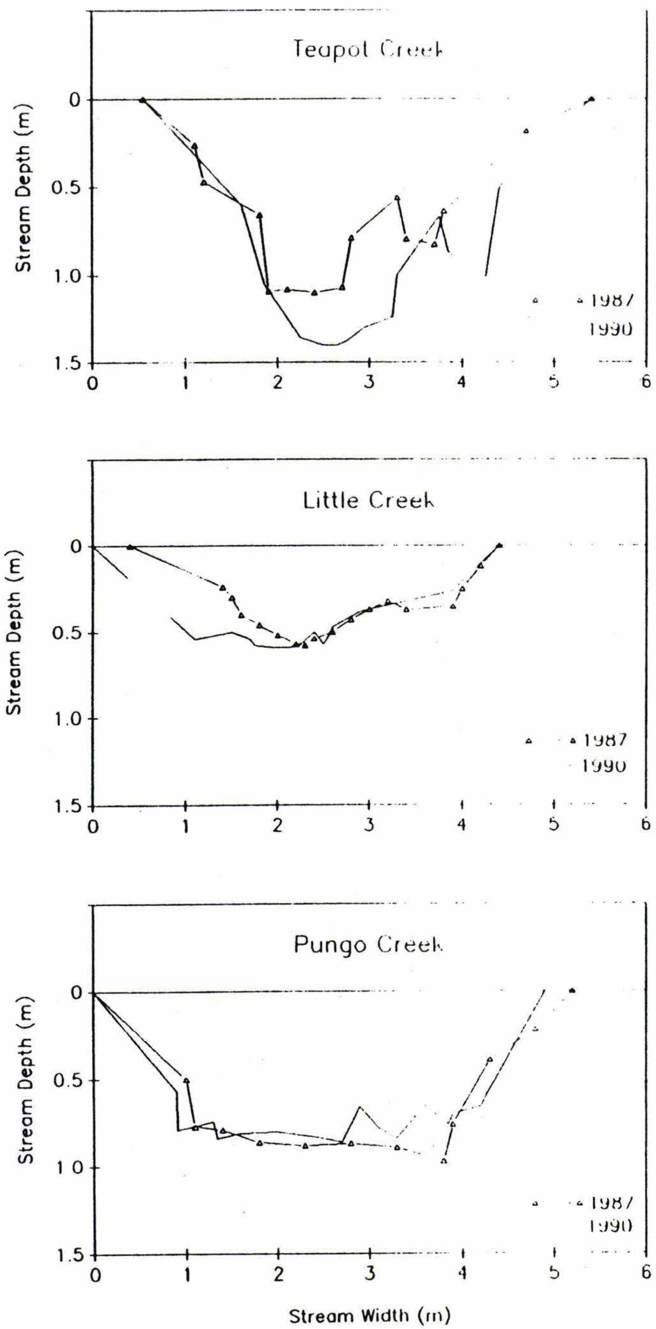
perspective (Figure 9). Teapot Creek downcut 0.5 m with a large boulder sliding into the channel from the right bank (Figure 9). Little Creek displayed cutting of the left bank from 1987 to 1990 by about 0.5 meters. Pungo Creek remained essentially unchanged between 1987 and 1990. EF Indian Creek displayed major right bank cutting of about 2.5 meters, and an increase in channel depth from 1987 to 1990. The channel profiles at L. Loon indicated channel filling from 1984 to 1990, perhaps in response to fine sediment input from upstream channel erosion (Figure 9).

Periphytic and Benthic Organic Matter: Periphyton chlorophyll a and AFDM was compared from 1979 through 1990 for the five streams (Figure 10, 11). All sites displayed a peak in AFDM in 1987, while Teapot Creek displayed a peak in chlorophyll a that was 4-10X higher in 1988 than any other year studied. Little Creek displayed a peak in chlorophyll a in 1983, four years after the Mortar Creek fire (Figure 10). Pungo Creek chlorophyll a levels remained essentially unchanged throughout the 10 years of study and this probably is due to the full canopy that is still present after the 1988 fire. EF Indian Creek displayed a small chlorophyll a peak in 1990 perhaps in response to a more open canopy resulting from the 1988 fire. The 1988 fire appeared to be more intense at Teapot than Pungo or EF Indian Creeks. Indeed, the riparian vegetation was unburned at the Pungo study site and minimally burned at EF Indian study site. Chlorophyll a peaked from 1982 through 1984 in L. Loon, with a major peak in 1984 (Figure 10). This increase in chlorophyll a may be a response to the 1979 fire.

Periphyton AFDM displayed a substantial peak, similar to chlorophyll, in 1987 and 1988 in Teapot Creek (Figure 11). Little Creek displayed a slight increase in AFDM in 1987 that was not present in the chlorophyll data, and showed a peak similar to chlorophyll in 1982 and 1983. Pungo Creek showed an increase in periphyton AFDM in 1987. Periphyton AFDM increased in 1987 and again in 1990 in EF Indian (Figure 11). This pattern was not observed for chlorophyll, although a slight increase in chlorophyll was present in 1990 in EF Indian. L. Loon Creek displayed similar increases in AFDM as in chlorophyll from 1982 through 1984, although L. Loon also displayed an AFDM peak in 1987 as did the other study streams (Figure 11).

Benthic organic matter was characterized and compared for 1980, 1988, and 1990. Teapot Creek had similar quantities of BOM in 1980 and 1988, then the quantity of BOM increased substantially in 1990 (by about 6X) relative to 1988 values (Table 8). The % charcoal of BOM also increased from 10% in 1988 to 19% in 1990, probably in response to the 1988 fire. Similar levels of BOM were found among years in EF Indian, with no differences indicated in the % charcoal of the BOM. Pungo Creek displayed trends similar to those of EF Indian for BOM and % charcoal (Table 8). The % charcoal decreased in Little Creek from 82% in 1980, as a response to the 1979 fire, to less than 10% charcoal in 1988 and 1990. However, no apparent differences were found in the quantity of BOM among years in Little Creek. The quantity of BOM was reduced by half in L. Loon Creek from 1980 to 1988, with similar values observed in 1988 and 1990. No trends were observed in the % charcoal of BOM among years in L. Loon Creek (Table 8).

Macroinvertebrate Analysis: Macroinvertebrates were analyzed for 1980, 1987,



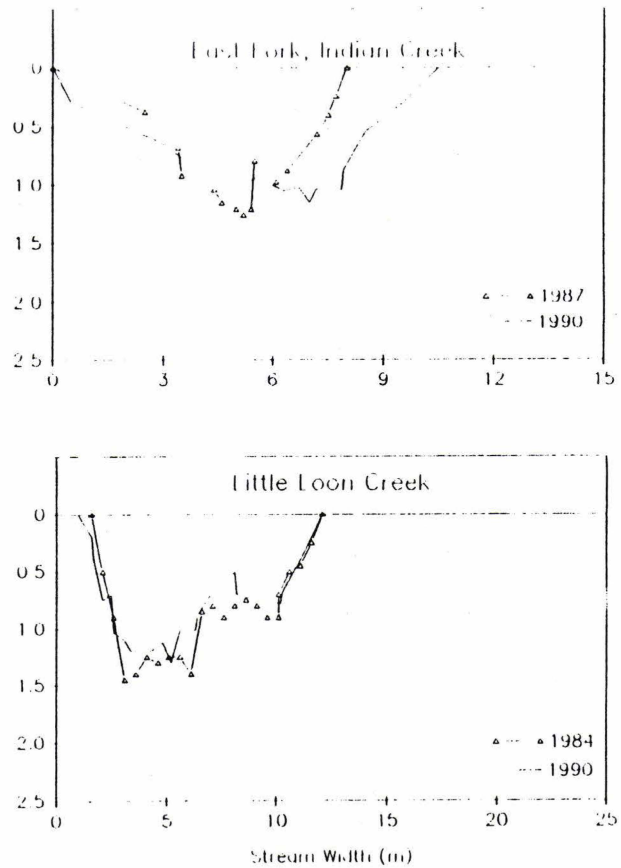


Figure 9. Cross sectional channel profile for each site in 1987 and 1990.

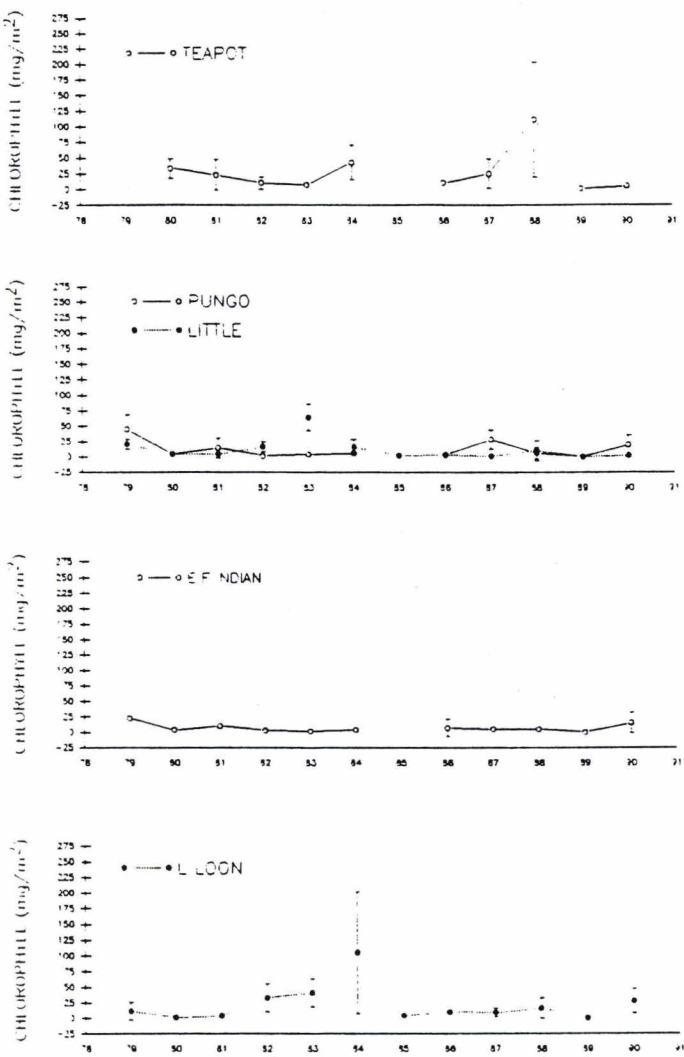


Figure10. Periphyton chlorophyll (mg/m^2) for streams in the Mortar Creek drainage. Samples were collected in July each year from 1979 through 1990.

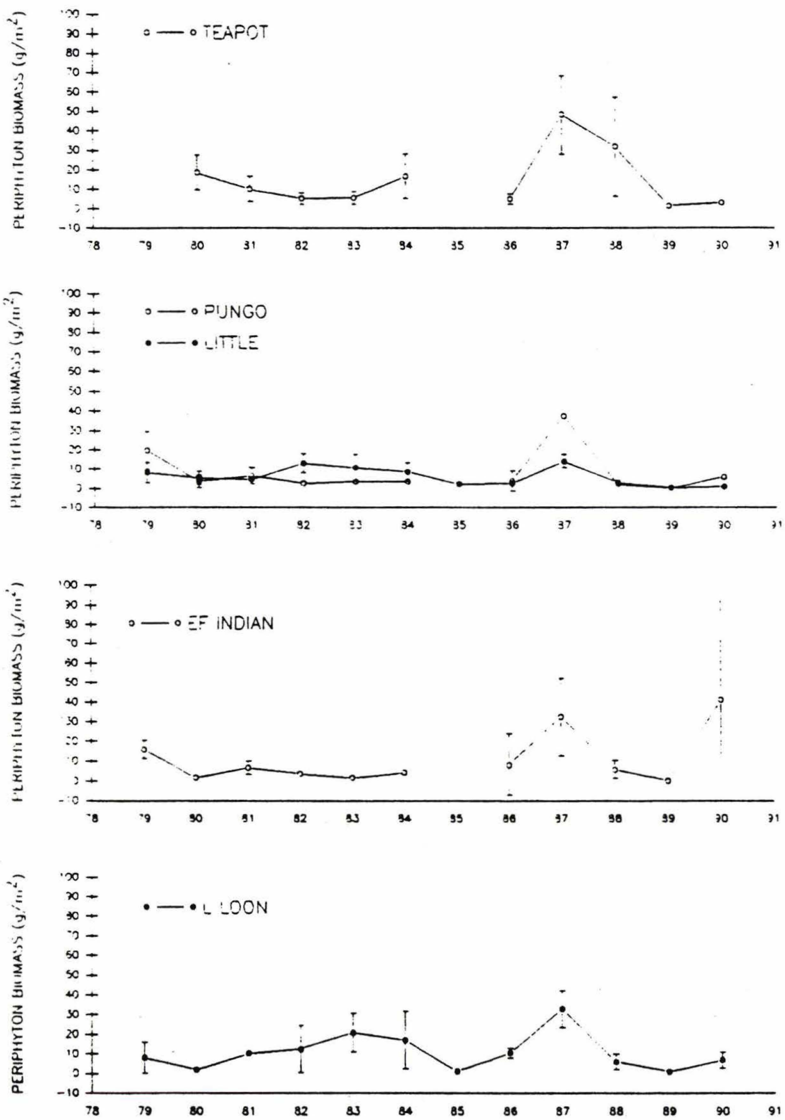


Figure 11 Periphyton biomass (g/m^2) as ash free dry mass for streams in the Mortar Creek drainage. Samples were collected in July each year from 1979 through 1990.

Table 8. Benthic organic matter (BOM; g/m^2) and % charcoal associated with Surber samples taken in July 1980, July 1988, and July 1990 from the Mortar Creek Fire study sites. N=5 for each site and date. C=control site, B=burn site.

SITE	BOM (g/m^2)						% CHARCOAL					
	1980		1988		1990		1980		1988		1990	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
TEAPOT CK.	20.9		15.0	6.9	87.6	68.6	6		8	10	19	6.5
EF INDIAN CK.	15.1		16.0	17.6	10.1	12.8	0		10	9	12	4.5
PUNGO CK.	13.9		13.4	13.5	11.0	6.0	0		10	8	10	9
LITTLE CK.	32.5		19.9	8.9	32.9	26.0	82		10	7	6	5.5
L LOON	21.5		7.3	0.9	8.8	10.0	0		8	3	1	1

1988, 1989, and 1990 in terms of mean abundance, mean biomass, species richness, and Shannon Diversity (H'). All sites displayed low abundances in 1980 (Figure 12). Abundance increased substantially from 1988 to 1989-90 in Teapot and Pungo Creeks, although little difference was observed between 1989 and 1990 (Figure 12). Macroinvertebrate abundance and biomass was low in 1989 compared to 1987, 1988 and 1990 values in EF Indian. Abundance was high in Little Creek for years 1987-1990 over values found in 1980. Abundance increased substantially in 1988-1990 in L. Loon compared to values in 1980 and 1987. The trends for biomass were similar to abundance for Teapot, Little and L. Loon Creeks, although being more pronounced in L. Loon. Pungo Creek displayed low biomass values in 1987 and 1988.

Species richness was greater in 1987 to 1990 compared to values in 1980 for all sites, although Little and L. Loon Creeks showed the most dramatic increase (Figure 12). EF Indian was the only site affected by the Battle Axe Fire that displayed a decrease in species richness in 1989. Shannon diversity was the same from 1987 to 1989 in Pungo Creek, then increased in 1990 to values found in 1980. Similar trends were apparent for species richness and Shannon diversity among years in Little and L. Loon Creeks, with low values for both in 1980. Apparently, Little and L. Loon Creeks were impacted highly by the Mortar Creek Fire. No major trends were observed in Shannon diversity (H') in streams affected by the Battle Axe Fire of 1988, whereas H' tended to decrease in Little and L. Loon Creeks in this same period. However, H' was higher, as was species richness, from 1988-1990 over values found in 1980 and 1987 in Teapot Creek suggesting a positive impact from fire.

DISCUSSION and CONCLUSIONS

Big Creek Study: Periphytic chlorophyll a and organic matter tended to be greater in reference sites than burn sites, whereas benthic organic matter was higher in burn sites than in reference sites. Charcoal comprised a substantial portion of the BOM in burn sites relative to reference sites. Benthic macroinvertebrates displayed greater abundance and biomass in reference sites compared to burn sites indicating an initial impact from wildfire to these stream systems. Macroinvertebrate species richness was reduced in burn streams, while the evenness among taxa was not different among burn and reference streams. The 50-year burn stream, Doe Creek, appeared more similar to reference sites than to burn sites for the parameters measured. Subtle differences in the ten most abundant taxa indicated a shift to more disturbance resistant species in the burn streams. For example, the highly mobile mayfly, Baetis, was relatively more abundant in burn streams than reference streams. Doe Creek displayed greater similarities in taxa relative abundance to reference streams than to burn streams.

These data suggest that the Golden Fire has had an initial impact on streams by changing the food resource base and altering the species composition among streams. The greater abundances of Simulium suggest higher levels or enhanced quality of seston (transported organic matter) in burn

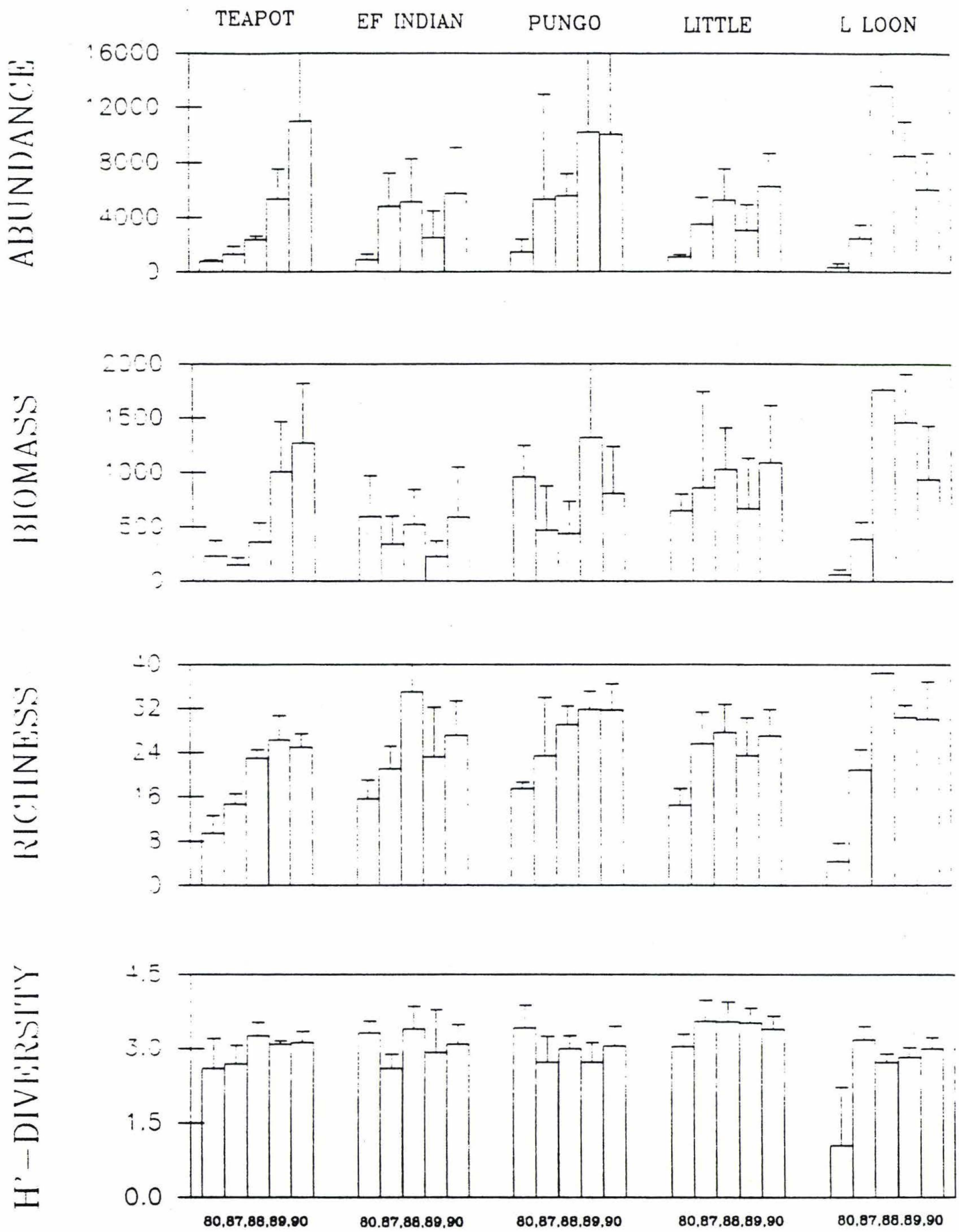


Figure 12. Mean macroinvertebrate abundance (#/m2), biomass (mg/m2), species richness, and species diversity (H') for selected study streams of the Mortar Creek Fire study for July 1980, 1987, 1988, 1989, and 1990. Bars represent +1 SD from the mean.

streams and Doe Creek compared to reference streams. The reduction in macroinvertebrate abundance and biomass in burn streams is attributed to physical processes because evenness values (Simpson's Index) were similar and relatively low among sites. Low Simpson's values suggest minimal influence by density dependent factors in controlling community structure, i.e. all species were impacted similarly. This conclusion is substantiated even in respect to Baetis. Baetis relative abundances were higher in burn streams, but absolute abundances were substantially lower. Further, the impact by wildfire differed among streams. At this point it is not clear if this is due to the inherent heterogeneity among streams or to differences in such things as stream size, fire intensity, or fire extent. We intend to address these points in future work in the region. Our results for Goat Creek are particularly puzzling for, although the values for macroinvertebrate abundance, biomass, and richness were comparable to other burn streams, those for BOM and % charcoal and periphytic chlorophyll and AFDM were exceptionally high. We have been told that Goat Creek was "back burned" (H & J Akenson, personal communication) and we observed that, at least in the lower reaches, this resulted in the burning of the riparian vegetation but not that of the adjacent side slopes. From this, we expected that runoff from the watershed would be less rapid and disturbance of the stream channel less severe than in streams where the whole watershed burned. The high BOM and periphyton values are in keeping with this interpretation but it is not supported by the low macroinvertebrate values.

The high similarity between Doe Creek and the reference sites suggest recovery may be completed in less than 50 years for that size stream. The impact of fire on streams reflects the intensity and timing of the disturbance in relation to stream size and proximity to potential colonists. Severe impacts by fire in headwater regions of a watershed are likely to markedly reduce recolonization by downstream drift and thereby impede recovery (e.g. Wallace 1990).

Future studies in the Frank Church Wilderness should be aimed at (1) documenting conditions over a wider range of stream sizes and watershed burn intensities, (2) further replicating (for increased statistical power and a better definition of mean response conditions) the number of streams of each type, and (3) examining additional streams in old burns of different age "classes" in the range 20 to $\geq$100 years.

Cliff Creek Study: The Cliff Creek study site was located outside the fire perimeter. The results indicate no difference in periphytic organic matter and benthic organic matter between prefire and postfire collection periods, probably because the extent of shading at the study site has not changed. However, the percent charcoal continued to increase from 1988 to 1990, suggesting that charcoal is being transported from upstream burned areas into the study reach. These data suggest that downstream sites may experience a lag period in the effect of wildfire as indicated in the temporal increase in charcoal in Cliff Creek. Both macroinvertebrate abundance and biomass were reduced the year following the fire, although no difference was observed in species richness. No effect on macroinvertebrates was seen in 1990.

A common problem in studying the impact of fire on streams is collecting prefire data from the same stream to serve as a "control" against which to

evaluate subsequent responses. The fortuitous collection of prefire data from Cliff Creek. as a part of another study, enabled us to avoid this problem. The before and after data from Cliff Creek support our findings on the impact of fire using reference streams to compare with burn streams. However, in Cliff Creek, the effects of fire may have been mitigated by the location of our sampling site outside of the fire perimeter. We intend to examine Cliff Creek within the fire perimeter and compare the results with data collected from the present study reach in the coming field season. This will add an important spatial dimension in the study of wildfire effects on stream systems.

Mortar Creek Study: Changes that occurred in Teapot, EF Indian, and Pungo Creeks (Battle Axe Fire-1988) were more variable but somewhat comparable to changes observed in Little and Little Loon Creeks (Mortar Creek Fire-1979) for the study period 1987-1990. The variability probably partly reflects differences of watershed fire extent and intensity. The watersheds of Pungo and EF Indian Creeks did not appear to have burned as much as the watershed of Teapot Creek. Indeed, the riparian vegetation was unburned at the study reaches along Pungo and EF Indian, while being burned intensively at Teapot Creek. Teapot Creek displayed a dramatic increase in macroinvertebrate abundance, biomass, richness, and H' probably reflecting the more open canopy. In addition, postfire runoff after the Battle Axe Fire may not have been as great as after the Mortar Creek Fire due to the ongoing drought, as evidenced in the low richness and H' values at Little and L. Loon Creeks in 1980. These results suggest that the impact of wildfire on stream ecosystems is a function of fire intensity in relation to present climatic factors.

ACKNOWLEDGMENTS

A number of individuals assisted in the field collection and laboratory processing of samples. These include: Douglas A. Andrews, Scott Bailey, Melissa Bowler, James T. Brock, Dale Bruns, James Check, Kenneth W. Cummins, Paul D. Dey, David Funk, Robert Gill, David Grant, Alan Hale, Scott Hart, Mike Haslett, Evelyn Hitchcock, Bryan Jamison, Don Johnson, Don Kendall, Peter Koetsier, Thomas LaPoint, Deron Lawrence, Peter W. Lawson, Nancy Jane Reid-Lawson, Tim Litke, Michael McIntyre, Justin Mann, Sharon Manuel, Rosanna Mattingly, Naresh Mehra, Janet Mihuc, Tim B. Mihuc, Jennye M. Minshall, Judy N. Minshall, Susannah C. Minshall, Greg C. Mladenka, John R. Moeller, David C. Moser, Cecily Nelson, Bruce Olenick, Michael Privett, Alan Raflo, Carl Richards, Lisa Reed, Greg Sautter, Bill Skinner, Terry Tiersch, Urs Uehlinger, Lynn Van Every, Robin L. Vannote, and Tim Whittier (those whose names are underlined participated in the 1990 study). We especially thank Jim and Holly Akenson, resident managers of the University of Idaho's Taylor Ranch Field Station, for their hospitality and for collecting benthic macroinvertebrates from Cliff Creek in November 1988 and July 1989. We also appreciate the help of Don and Jody Mitchell and their staff at the Flying B Ranch and the USFS Trail Crew in the recovery of our horses. In the course of

our research on effects of wildfire on streams in the Frank Church "River of No Return" Wilderness a number of personnel from the US Forest Service have befriended us or actively aided our research efforts. In this regard we would especially like to acknowledge the help and cooperation of the following: David Burns, Al Dunham, Lou Freeman, Gary Fullmer, Bud Hamilton, Ron Hanson, Tom Harbour, Leon Jadlowski, Bruce May, Wayne Somes, and Russ Thurow (formerly with Idaho Fish & Game).

LITERATURE CITED

American Public Health Association. 1989. Standard methods for the examination of water and wastewater. APHA, New York.

Bovee, K. D. and R. Milhous. 1978. Hydraulic simulation in instream flow studies: theory and techniques. Cooperative Instream Flow Service Group, Western Energy and Land Use Team, U.S. Fish and Wildlife Service, Fort Collins, Colorado.

Buchanan, T. J. and W. P. Somers. 1969. Discharge measurements of gaging stations. In: Techniques of Water Resources Investigations. Book 3, Chapter A8. U.S. Geol. Survey.

Greeson, P. E., T. A. Ehlke, G. A. Irwin, B. W. Lium, and K. V. Slack (eds). 1977. Methods for collection and analysis of aquatic biological and microbiological samples. Techniques of Water-Resources Investigations. U.S. Geol. Surv. 322 p.

Gregory, K. J. and D. E. Walling. 1973. Drainage basin form and process. J. Wiley & Sons, New York.

Leopold, L. B. 1970. An improved method for size distribution of stream bed gravel. Water Resources Research 6:1357-1366.

Lind, O. T. 1979. Handbook of common methods in limnology. 2nd edition. C. V. Mosby Co., St. Louis. 199 p.

Lorenzen, C. J. 1966. A method for the continuous measurement of *in vivo* chlorophyll concentration. Deep-Sea Research 13:223-227.

Merritt, R. W. and K. W. Cummins (eds). 1984. An introduction to the aquatic insects. 2nd edition. Kendall/Hunt Publishing Co., Dubuque, Iowa 722p.

Platts, W. S., W. F. Megahan, and G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. U. S. Forest Service General Technical Report INT-138. 70 p.

Stockner, J. G. and F. A. J. Armstrong. 1971. Periphyton of the Experimental Lakes Area, northwestern Ontario. J. Fish. Res. Bd. Canada 28:215-229.

Talling, J. R. 1973. The application of some electrochemical methods to the measurement of photosynthesis and respiration in fresh waters. Freshwat. Biol. 3:335-362.

Weber, C. I. (ed.) 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. EPA-670/ 4-73-001 U.S. Environmental Protection Agency, Cincinnati. 53 p.

Wallace, J. B. 1990. Recovery of lotic macroinvertebrate communities from disturbance. Environmental Management 14:605-620.

Appendix 1. Mean numbers of individual taxa per square meter (and standard deviations) for study sites in the Big Creek drainage basin of central Idaho in summer 1990.

	GOAT		DUNCE		COUGAR		CLIFF		WF CAVE		MTH CAVE		DOE	
FFG/SPECIES	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
PREDATORS														
Alloperla											46.9	78.6		
Calineuria					27.7	24.6			6.4	14.3	6.4	9.5		
Ceratopogonidae	55.5	118.2	72.6	144.6	19.2	42.9	4.3	9.5	17.1	16.2	27.7	24.6	8.5	8.9
Ceratopogonidae pupae									14.9	27.8				
Chloroperlidae							44.8	100.2					2.1	4.8
Dicronota	4.3	9.5							8.5	19.1				
Dytiscidae											4.3	9.5		
Empididae											4.3	9.5		
Glutops sp.							6.4	9.5			21.3	20.0	49.1	52.6
Hemiptera	42.7	59.9												
Hesperoperla											4.3	9.5		
Hexatoma sp.					49.1	49.2			40.5	28.6	49.1	30.7		
Hydracarina sp. 1	49.1	38.9	4.3	9.5	14.9	14.5	51.2	48.5	79.0	50.4	623.1	446.4	79.0	55.8
Hydracarina sp. 2	25.6	46.3	8.5	11.7	2.1	4.8	12.8	17.5	21.3	37.0	6.4	14.3	2.1	4.8
Isoperla											236.9	129.0		
Limnophila											4.3	5.8		
Limoniinae					14.9	33.4	2.1	4.8						
Limoniinae pupae							2.1	4.8						
Nematoda							121.6	214.5	134.4	236.4	36.3	50.9	68.3	94.7
Pedicia sp.													6.4	9.5
Perlidae													61.9	44.9
Perlodidae							34.1	33.2			17.1	38.2	2.1	4.8
Rhyacophila sp.									4.3	9.5	2.1	4.8	2.1	4.8
Rhyacophila pupae											6.4	9.5		
Rhyacophila angelita					2.1	4.8	2.1	4.8			4.3	9.5		
Rhyacophila hyalinata									17.1	23.4	81.1	62.9		
Rhyacophila bifila							6.4	9.5	8.5	13.9				
Rhyacophila vagrita					10.7	15.1	17.1	20.8			2.1	4.8	6.4	9.5
Rhyacophila vespula					2.1	4.8	27.7	34.2	157.9	85.5	59.8	24.6	96.0	79.5
Suwallia sp.	76.8	72.1	36.3	24.6	72.6	23.1	326.5	350.1	119.5	95.3	243.3	218.5	411.9	189.8
Tipulidae							4.3	5.8	2.1	4.8			2.1	4.8
Turbellaria									12.8	11.7	34.1	38.0		
Coleoptera	2.1	4.8					2.1	4.8						
Diptera adult	27.7	31.7	2.1	4.8	8.5	8.9	2.1	4.8			2.1	4.8	4.3	9.5
[illegible]aosoridae	4.3	5.8												

Appendix 1. (continued)

FFG/SPECIES	GOAT mean	GOAT sd	DUNCE mean	DUNCE sd	COUGAR mean	COUGAR sd	CLIFF mean	CLIFF sd	WF CAVE mean	WF CAVE sd	MTH CAVE mean	MTH CAVE sd	DOE mean	DOE sd
GATHERERS														
Ameletus sp.									2.1	4.8				
Antocha sp.											19.2	26.6		
Antocha pupae											4.3	5.8		
Capniidae							6.4	14.3			23.5	28.6		
Chelifera sp.	32.0	71.6			17.1	17.9	38.4	35.9	42.7	54.4	14.9	17.9		
Collembola			2.1	4.8	2.1	4.8	2.1	4.8			4.3	5.8	2.1	4.8
Cyrnellus							2.1	4.8					2.1	4.8
Dixa sp.	14.9	20.8	2.1	4.8					4.3	9.5				
Elmidae											2.1	4.8		
Ephemerella grandis											2.1	4.8		
Ephemerella sp.	6.4	5.8												
Hemerodromia sp.							4.3	9.5						
Heterlimnius sp.	303.0	280.7	68.3	84.6	593.3	382.8	672.2	369.7	1124.6	699.0	2114.8	1062.2	819.5	527.8
Hyallela azteca			2.1	4.8										
Hydrophilidae	2.1	4.8												
Lepidostoma			6.4	9.5										
Leptophlebia											6.4	9.5		
Narpus sp.			57.6	101.7							2.1	4.8		
Tricorythodes sp.			17.1	38.2										
Moselyana sp.							12.8	28.6						
Moselyana pupae			2.1	4.8										
Moselyana adult	6.4	14.3												
Paraleptophlebia sp.									89.6	88.2			10.7	23.9
Pericoma									2.1	4.8				
Rhyacophila acropedes	19.2	17.5			17.1	32.5	23.5	23.1	44.8	59.1	12.8	13.9	6.4	9.5
Serratella tibialis									42.7	89.6	106.7	43.3		
SCRAPERS														
Baetis sp.	4.3	9.5												
Baetis bicaudatus	44.8	66.8	19.2	20.5	315.8	239.6	723.4	721.0	2.1	4.8			21.3	37.0
Baetis intermedius					6.4	14.3	140.8	309.0	8.5	19.1	537.8	302.0	8.5	11.7
Baetis tricaudatus	2.1	4.8									4.3	5.8	10.7	23.9
Cinygmula sp.							202.7	249.3	14.9	16.2	21.3	32.9	136.6	110.2
Drunella colordensis					4.3	9.5			53.4	57.0				
Drunella doddsi							2.1	4.8						
Drunella flavilinea					4.3	5.8	51.2	41.6			72.6	76.3	10.7	23.9
Drunella spinifera					4.3	5.8	2.1	4.8						

Appendix 1. (continued)

FFG/SPECIES	GOAT mean	GOAT sd	DUNCE mean	DUNCE sd	COUGAR mean	COUGAR sd	CLIFF mean	CLIFF sd	WF CAVE mean	WF CAVE sd	MTH CAVE mean	MTH CAVE sd	DOE mean	DOE sd
Epeorus sp.	8.5	19.1												
Epeorus deceptivus							2.1	4.8						
Epeorus grandis							2.1	4.8						
Epeorus longimanus							2.1	4.8			44.8	56.2		
Ephemerella inermis					17.1	38.2			4.3	9.5			2.1	4.8
Gastropoda			6.4	5.8			2.1	4.8						
Glossosoma sp.							3.5	5.2						
Heptageniidae	6.4	14.3			85.4	115.9	10.7	13.1	2.1	4.8	14.9	22.1	19.2	25.5
Neophylax					49.1	48.7	42.7	36.2			17.1	17.9	12.8	11.7
Rhithrogena											2.1	4.8		
Taenyopteryg													2.1	4.8
Ephemerella hystrix							6.4	14.3						
SHREDDERS														
Capnia sp.									70.4	107.1				
Cryptochia													2.1	4.8
Lara sp.											4.3	9.5		
	3.2	6.0			2.1	4.8							6.4	9.5
Limnephilidae									2.1	4.8			2.1	4.8
Nemoura	4.3	9.5			2.1	4.8								
Onocosmoeus sp.									8.5	13.9	2.1	4.8		
Visoka cataractae	19.2	37.3												
Yoroperla brevis	6.4	9.5	79.0	38.9	10.7	10.7	21.3	18.5	757.6	293.5			74.7	42.7
Zapada cinctipes	89.6	78.6	57.6	99.7	64.0	66.2	117.4	170.4			4.3	5.8	6.4	9.5
Zapada oregonesis									40.5	26.6				
Amphinemura sp.	8.5	8.9									2.1	4.8	61.9	48.0
FILTERERS														
Arctopsyche sp.											2.1	4.8		
Arctopsyche pupae											2.1	4.8		
Brachycentrus sp.							6.4	14.3			87.5	53.6		
Oligoplectrum							6.4	9.5						
Ostracoda	463.1	425.6	17.1	16.2	51.2	37.3	151.5	46.1	1568.5	685.9	744.8	759.4	1218.5	691.2
Parapsyche elsis			8.5	4.8	6.4	14.3	2.1	4.8	2.1	4.8			6.4	5.8
Pisidium	2.1	4.8												

Appendix 1. (continued)

FFG/SPECIES	GOAT mean	GOAT sd	DUNCE mean	DUNCE sd	COUGAR mean	COUGAR sd	CLIFF mean	CLIFF sd	WF CAVE mean	WF CAVE sd	MTH CAVE mean	MTH CAVE sd	DOE mean	DOE sd
Simulium sp.					21.3	30.2	155.8	194.7	74.7	115.9	40.5	38.8	102.4	84.6
Simulium pupae	106.7	193.4	23.5	20.5			14.9	16.2						
MINERS														
Chironomidae sp. 1	143.0	137.0	46.9	44.4	245.4	149.2	864.3	1274.7	917.6	1187.6	1449.0	434.6	283.8	292.1
Chironomidae sp. 2	12.8	13.9			10.7	15.1	136.6	108.7			234.7	110.9	74.7	46.5
Chironomidae adult							12.8	13.9			10.7	10.7		
Oligochaeta sp. 1	91.8	52.1	42.7	27.2	70.4	50.9	706.4	796.3	262.5	318.8	2161.7	642.1	106.7	124.2
Oligochaeta sp. 2	44.8	78.6												
Oligochaeta adult									8.5	11.7				
OTHERS														
Arachnids							14.9	17.9					68.3	96.2
Fish					6.4	9.5							2.1	4.8
Homoptera													2.1	4.8
Hymenoptera							2.1	4.8			2.1	4.8	10.7	10.7
Other terrestrials	40.5	51.4	6.4	14.3	19.2	31.5	17.1	16.2	12.8	11.7	4.3	5.8	21.3	21.3

Appendix 2. Mean biomass (mg/m2) and standard deviation of individual taxa for study sites in the Big Creek drainage basin of central Idaho in summer 1990.

	GOAT		DUNCE		COUGAR		CLIFF		WF CAVE		MTH CAVE		DOE	
FFG/SPECIES	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
PREDATORS														
Alloperla											9.04	13.82		
Calineuria					2.78	2.08			0.93	1.85	52.06	63.96		
Ceratopogonidae	6.52	12.33	1.12	1.88	0.94	1.89	0.19	0.38	1.01	1.00	1.27	0.81	0.18	0.17
Ceratopogonidae pupae									20.93	31.80				
Chloroperlidae							1.18	2.35					2.24	4.48
Dicronota	0.23	0.45							1.34	2.67				
Dytiscidae											3.64	7.29		
Empididae											1.40	2.80		
Glutops sp.							12.01	14.79			5.47	7.56	70.11	50.26
Hemiptera	1.73	2.06												
Hesperoperla											18.98	37.96		
Hexatoma sp.					21.60	24.36			3.37	2.40	38.44	16.68		
Hydracarina sp. 1	4.25	6.17	0.07	0.14	0.92	0.90	1.11	1.08	1.73	1.38	13.67	7.68	2.70	1.59
Hydracarina sp. 2	0.31	0.51	0.25	0.34	0.04	0.09	0.35	0.38	0.59	0.93	0.09	0.18	0.20	0.39
Isoperla											134.19	65.36		
Limnophila											2.98	4.14		
Limoniinae					4.73	9.47	0.13	0.27						
Limoniinae pupae							4.13	8.26						
Nematoda							1.26	1.48	1.44	2.27	0.65	0.94	0.36	0.44
Pedicia sp.													0.24	0.47
Perlidae													46.45	59.05
Perlodidae							8.29	7.05			0.80	1.59	0.42	0.85
Rhyacophila sp.									5.10	10.20	0.16	0.32	6.32	12.64
Rhyacophila pupae											7.13	9.22		
Rhyacophila angelita					1.38	2.77	0.17	0.35			0.77	1.55		
Rhyacophila hyalinata									1.71	2.13	18.93	12.65		
Rhyacophila bifila							39.06	50.11	32.91	46.61				
Rhyacophila vagrita					4.13	7.91	0.46	0.49			0.26	0.52	3.92	5.13
Rhyacophila vespula					0.16	0.32	1.65	1.41	17.95	13.25	2.75	0.65	7.17	5.10
Suwallia sp.	11.63	19.46	1.53	1.11	2.43	1.56	17.91	16.69	8.10	6.02	17.67	14.39	34.17	11.90
Tipulidae							0.29	0.36	2.46	4.93			0.00	0.01
Turbellaria									3.88	3.13	5.54	5.48		
Coleoptera	0.07	0.14					0.20	0.39						
Diptera adult	2.38	2.10	0.57	1.15	1.82	2.25	0.34	0.67			0.44	0.88	0.28	0.55
Chaosoridae	0.12	0.20												

Appendix 2. (continued)

	GOAT		DUNCE		COUGAR		CLIFF		WF CAVE		MTH CAVE		DOE	
FFG/SPECIES	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
GATHERERS														
Ameletus sp.									0.19	0.38				
Antocha sp.											13.39	18.39		
Antocha pupae											4.22	5.51		
Capniidae							0.33	0.65			2.14	2.89		
Chelifera sp.	0.28	0.57			1.82	2.56	3.13	3.20	2.95	3.61	2.32	2.46		
Collembola			0.02	0.04	0.22	0.43	0.04	0.09			0.31	0.40	0.33	0.67
Cyrnellus							0.01	0.03					0.10	0.20
Dixa sp.	2.54	3.11	0.20	0.40					0.16	0.32				
Elmidae											0.43	0.86		
Ephemerella grandis											56.66	113.32		
Ephemerella sp.	0.33	0.29												
Hemerodromia sp.							0.10	0.19						
Heterlimnius sp.	54.00	53.50	6.70	8.65	70.96	36.94	72.52	43.52	80.66	44.13	189.93	69.53	56.86	43.33
Hyallela azteca			0.14	0.28										
Hydrophilidae	0.14	0.28												
Lepidostoma			7.40	10.09										
Leptophlebia											0.24	0.29		
Narpus sp.			127.75	203.15							1.56	3.12		
Tricorythodes sp.			4.78	9.56										
Moselyana sp.							0.09	0.19						
Moselyana pupae			0.06	0.11										
Moselyana adult	1.09	2.17												
Paraleptophlebia sp.									1.84	1.44			0.31	0.61
Pericoma									2.50	5.00				
Rhyacophila acropedes	49.60	61.54			2.42	4.36	86.61	82.61	16.14	17.14	3.91	4.40	5.31	9.76
Serratella tibialis									1.47	2.06	9.00	5.03		
SCRAPERS														
Baetis sp.	0.98	1.95												
Baetis bicaudatus	1.34	1.74	0.39	0.21	18.78	13.24	37.81	23.30	0.20	0.41			3.79	4.69
Baetis intermedius					1.05	2.10	20.61	40.77	1.26	2.51	71.78	46.65	0.65	0.80
Baetis tricaudatus	0.09	0.18									2.35	2.92	0.66	1.31
Cinygmula sp.							33.95	36.86	6.88	7.27	1.15	1.65	17.57	16.59
Drunella colordensis					1.66	3.33			69.82	76.67				
Drunella doddsi							15.98	31.95						
Drunella flavilinea					2.41	2.96	22.08	21.21			61.90	59.08	11.62	23.24
Drunella spinifera					20.51	25.50	6.80	13.61						

Appendix 2. (continued)

FFG/SPECIES	GOAT mean	GOAT sd	DUNCE mean	DUNCE sd	COUGAR mean	COUGAR sd	CLIFF mean	CLIFF sd	WF CAVE mean	WF CAVE sd	MTH CAVE mean	MTH CAVE sd	DOE mean	DOE sd
Epeorus sp.	0.10	0.20												
Epeorus deceptivus							10.37	20.74						
Epeorus grandis							13.50	27.00						
Epeorus longimanus							1.01	2.01			21.69	35.74		
Ephemerella inermis					0.25	0.50			0.34	0.67			0.06	0.12
Gastropoda			1.72	1.52			0.10	0.20						
Glossosoma sp.							2.50	4.20						
Heptageniidae	0.36	0.71			4.09	6.19	0.67	0.98	0.16	0.32	2.41	3.00	15.55	12.89
Neophylax					5.15	5.49	13.07	10.33			5.79	5.97	3.40	3.28
Rhithrogena											3.94	7.88		
Taenyopterygidae													0.22	0.45
Ephemerella hystrix							3.80	7.61			31.10	30.10		
SHREDDERS														
Capnia sp.									6.43	9.16				
Cryptochia														
Lara sp.											28.25	56.50		
Lepidoptera sp.	45.00	90.00			20.35	40.69							3.16	4.42
Limnephilidae									10.50	20.99			10.50	20.99
Nemoura	0.31	0.61			1.94	3.88								
Onocosmoeus sp.									43.94	58.01	44.48	88.95		
Visoka cataractae	2.32	4.13												
Yoroperla brevis	4.15	5.08	40.01	74.12	0.39	0.61	5.73	5.13	356.39	193.71			34.61	33.45
Zapada cinctipes	3.69	4.50	1.66	2.79	3.22	3.20	4.[illegible]	[illegible]			0.24	0.39	0.82	1.09
Zapada oregonesis									3.29	1.30				
Amphinemura sp.	2.31	1.90									0.03	0.06	1.23	0.64
FILTERERS														
Arctopsyche sp.											16.56	33.12		
Arctopsyche pupae											48.60	97.19		
Brachycentrus sp.							0.36	0.72						
Oligoplectrum							2.63	3.50						
Ostracoda	13.14	7.48	1.07	1.49	0.82	0.36	3.37	1.51	38.70	22.56	20.82	21.94	20.26	8.29
Parapsyche elsis			6.66	4.24	107.77	215.53	78.53	157.06	2.39	4.78			19.62	19.21
Pisidium	1.00	2.00												

Appendix 2. (continued)

FFG/SPECIES	GOAT		DUNCE		COUGAR		CLIFF		WF CAVE		MTH CAVE		DOE	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Simulium sp.					3.48	4.51	17.40	18.12	7.01	11.19	1.74	1.44	6.30	3.82
Simulium pupae	17.47	25.27	0.78	0.58			9.57	8.70						
MINERS														
Chironomidae sp. 1	7.19	5.00	1.46	1.40	7.53	3.64	20.52	20.38	28.06	26.37	72.97	27.35	8.35	7.89
Chironomidae sp. 2	0.39	0.37			0.53	0.75	4.37	2.97			10.52	2.04	1.47	1.08
Chironomidae adult							0.51	0.61			0.53	0.50		
Oligochaeta sp. 1	54.38	25.81	196.30	189.72	0.71	1.05	32.88	44.75	104.40	128.35	41.08	14.80	2.49	2.70
Oligochaeta sp. 2	136.08	270.20												
Oligochaeta adult									0.40	0.57				
							0.10	0.12					2.70	4.50
OTHERS														
Arachnids														
Fish					73.58	92.16							14.52	29.04
Homoptera													1.12	2.25
Hymenoptera							0.92	1.84			0.36	0.73	2.35	2.20
Other terrestrials	8.38	4.79	5.24	10.47	1.10	1.63	8.44	14.71	15.57	19.19	1.25	2.11	4.68	4.34